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ILLUSTRATED BY NEARLY 300 ENGRAVINGS.

PRACTICAL CARPENTRY

BEING A GUIDE TO THE

CORRECT WORKING AND LAYING OUT OF ALL KINDS OF CARPENTERS' AND JOINERS' WORK.

With the Solutions of the Various Problems in Hip-Roofs, Gothic Work, Centering, Splayed Work, Joints and Jointing, Hinging, Dovetailing, Mitering, Timber Splicing, Hopper Work, Skylights, Raking Mouldings, Circular Work, Etc., Etc.

TO WHICH IS PREFIXED A THOROUGH TREATISE ON

"CARPENTERS' GEOMETRY."

BY

FRED. T. HODGSON

AUTHOR OF "THE STEEL SQUARE AND ITS USES," "THE BUILDER'S GUIDE AND ESTIMATOR'S PRICE BOOK," "THE SLIDE RULE AND HOW TO USE IT," ETC., ETC.

:o:

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PREFACE.

In offering this Work on Carpentry to the American Carpenter and Joiner, the author desires it to be understood that the work is not intended to take the place of any of the larger and more exhaustive works on the subject; but is designed more particularly for use as a hand-book by the workman that has not had time or opportunity to thoroughly commit to memory the principles it contains, and to occupy a small corner in the workman's tool chest, so that it may be referred to for consultation whenever circumstances require it.

It is quite true that many similar books have been written on the subject, each one of which possesses more or less merit, and the enquiring and progressive workman will make an effort to procure a copy of each kind, so that he may get at the readiest methods of performing the various operations of getting the lengths and angles of rafters, cuts and curves for circular roofs, and lines for hoppers, raking mouldings and other beveled work; but there are thousands of workmen whose limited means will not permit of their purchasing a great number of these books, and who can not afford to buy the high-priced volumes which contain all the ordinary workman would require to know. It is for these men this manual is prepared; and the author flatters himself that he has been able to string together a greater amount of real practical matter in this little work than was ever before offered for three times its price. Another thing too, which gives the work more value, is the fact that every rule and solution contained in it can be depended upon as reliable, as an experience of many years in the supervision of workmen has given the author ample opportunities to practically test nearly every rule the book contains.

Almost everything of a theoretical nature has been avoided, so as to bring its utility within the grasp of those workmen who have not had the benefit of a common school education, and within the understanding of every apprentice boy. It has been deemed necessary to introduce a chapter on the formation of geometrical figures, so as to give the reader the necessary knowledge required to construct understandingly the figures that follow in the work; but everything of a mystifying nature has been kept out, so that it is hoped the reader will not get frightened at the threshold and drop the book because of the geometrical figures that confront him. It must be borne in mind that all figures described by pen or pencil, that have for their object the delineation of roofs, house plans, bridges, or other like work, are composed of geometrical combinations, and every mechanic has to meet these combinations every day, in some shape or other, when pursuing his regular occupation, and it is therefore quite necessary that he should know something of the principles that underlie the construction of the drawings he works after.

It need hardly be said here that the material for this work has been drawn from a large number of sources, as anyone at all conversant with the science of carpentry and joinery will readily discover that such has been the case. Nearly every work of importance, from those of Nicholson down to Newland and Hatfield, has been consulted and drawn from to make the work now presented. Thanks are due the publishers for their liberality in keeping the price of this book—which is necessarily an expensive one to publish—at a sum which places it within the reach of every workman in the country.

It is believed the book will be appreciated by the persons for whom it is designed, and that it may prove interesting, useful, and consequently profitable, to all who have use for it, is the wish of

THE AUTHOR.

New York.

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PRACTICAL CARPENTRY.

PART I.—GEOMETRY.

BEFORE a knowledge of geometry can be acquired, it will be necessary to become acquainted with some of the terms and definitions used in the science of geometry, and to this end the following terms and explanations are given, though it must be understood that these are only a few of the terms used in the science, but they are sufficient for our purposes:

1. A *Point* has position but not magnitude. Practically, it is represented by the smallest visible mark or dot, but geometrically understood, it occupies no space. The extremities or ends of lines are points; and when two or more lines cross one another, the places that mark their intersections are also points.

2. A *Line* has length, without breadth or thickness, and, consequently, a true geometrical line cannot be exhibited; for however finely a line may be drawn, it will always occupy a certain extent of space.

3. A *Superficies* or *Surface* has length and breadth, but no thickness. For instance, a shadow gives a very good representation of a superficies: its length and breadth can be measured; but it has no depth or substance. The quantity of space contained in any plane surface is called its area.

4. A *Plane Superficies* is a flat surface, which will coincide with a straight line in every direction.

5. A *Curved Superficies* is an uneven surface, or such as will not coincide with a straight line in all directions. By the term surface is generally understood the outside of any body or object; as, for instance, the exterior of a brick or stone, the boundaries of which are represented by lines, either straight or curved, according to the form of the object. We must always bear in mind, however, that the lines thus bounding the figure occupy no part of the surface; hence the lines or points traced or marked on any body or surface, are merely symbols of the true geometrical lines or points.

6. A *Solid* is anything which has length, breadth and thickness; consequently, the term may be applied to any visible object containing substance; but, practically, it is understood to signify the solid contents or measurement contained within the different surfaces of which any body is formed.

7. *Lines* may be drawn in any direction, and are termed straight, curved, mixed, concave, or convex lines, according as they correspond to the following definitions.

8. A *Straight Line* is one every part of which lies in the same direction between its extremities, and is, of course, the shortest distance between two points, as from A to B, Fig. 1.

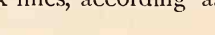


Fig. 1.

9. A *Curved Line* is such that it does not lie in a straight direction between its extremities, but is continually changing by inflection. It may be either regular or irregular.

10. A *Mixed* or *Compound Line* is composed of straight and curved lines, connected in any form.

11. A *Concave* or *Convex Line* is such that it cannot be cut by a straight line in more than two points; the concave or hollow side is turned towards the straight line, while the convex or swelling side looks away from it. For instance, the inside of a basin is concave—the outside of a ball is convex.

12. *Parallel Straight Lines* have no inclination, but are everywhere at an equal distance from each other; consequently they can never meet, though produced or continued to infinity in either or both directions. Parallel lines may be either straight or curved,

provided they are equally distant from each other throughout their extension.

13. *Oblique* or *Converging Lines* are straight lines, which, if continued, being in the same plane, change their distance so as to meet or intersect each other.

14. A *Plane Figure, Scheme, or Diagram*, is the lineal representation of any object on a plane surface. If it is bounded by straight lines, it is called a rectilineal figure; and if by curved lines, a curvilineal figure.

15. An *Angle* is formed by the inclination of two lines meeting in a point: the lines thus forming the angle are called the sides; and the point where the lines meet is called the *vertex* or *angular point.*

When an angle is expressed by three letters, as A B C, Fig. 2, the middle letter B should always denote the angular point: where

Fig. 2.

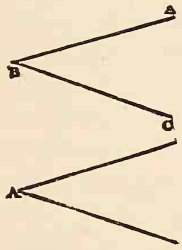


Fig. 3.

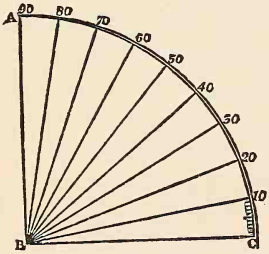


Fig. 4.

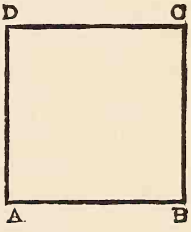


Fig. 5.

there is only one angle, it may be expressed more concisely by a letter placed at the angular point only, as the angle at A, Fig. 3.

16. The quantity of an angle is estimated by the arc of any circle contained between the two sides or lines forming the angle; the junction of the two lines, or vertex of the angle, being the centre from which the arc is described. As the circumferences of all circles are proportional to their diameters, the arcs of similar sectors also bear the same proportion to their respective circumferences; and, consequently, are proportional to their diameters, and, of course, also to their radii or semi-diameters. Hence, the

proportion which the arc of any circle bears to the circumference of that circle, determines the magnitude of the angle. From this it is evident that the quantity or magnitude of angles does not depend upon the length of the sides or radii forming them, but wholly upon the number of degrees contained in the arc cut from the circumference of the circle by the opening of these lines. The circumference of every circle is divided by mathematicians into 360 equal parts, called degrees; each degree being again subdivided into 60 equal parts, called minutes, and each minute into 60 parts, called seconds. Hence, it follows that the arc of a quarter circle or quadrant includes 90 degrees; that is, one-fourth part of 360 degrees. By dividing a quarter circle, that is, the portion of the circumference of any circle contained between two radii forming a right angle, into 90 equal parts, or, as is shown in Fig. 4, into nine equal parts of 10 degrees each, then drawing straight lines from the centre through each point of division in the arc; the right angle will be divided into nine equal angles, each containing 10 degrees. Thus, suppose B C the horizontal line, and A B the perpendicular ascending from it, any line drawn from B—the centre from which the arc is described—to any point in its circumference, determines the degree of inclination or angle formed between it and the horizontal line B C. Thus, a line from the centre B to the tenth degree, separates an angle of 10 degrees, and so on. In this manner the various slopes or inclinations of angles are defined.

17. A *Right Angle* is produced by one straight line standing upon another, so as to make the adjacent angles equal. This is what workmen call "square," and is the most useful figure they employ.

18. An *Acute Angle* is less than a right angle, or less than 90 degrees.

19. An *Obtuse Angle* is greater than a right angle or square, or more than 90 degrees.

The number of degrees by which an angle is less than 90 degrees is called the complement of the angle. Also, the difference between an obtuse angle and a semicircle, or 180 degrees, is called the supplement of that angle.

20. *Plane Figures* are bounded by straight lines, and are named according to the number of sides which they contain. Thus, the space included within three straight lines, forming three angles, is called a trilateral figure or triangle.

21. A *Right-Angled Triangle* has one right angle: the sides forming the right angle are called the base and perpendicular; and the side opposite the right angle is named the hypothenuse. An equilateral triangle has all its sides of equal length. An isosceles triangle has only two sides equal; a scalene triangle has all its sides unequal. An acute-angled triangle has all its angles acute, and an obtused-angled triangle has one of its angles only obtuse.

The triangle is one of the most useful geometrical figures for the mechanic in taking dimensions; for since all figures that are bounded by straight lines are capable of being divided into triangles, and as the form of a triangle cannot be altered without changing the length of some one of its sides, it follows that the true form of any figure can be preserved if the length of the sides of the different triangles into which it is divided is known; and the area of any triangle can easily be ascertained by the same rule, as will be shown further on.

Quadrilateral Figures are literally four-sided figures. They are also called quadrangles, because they have four angles.

22. A *Parallelogram* is a figure whose opposite sides are parallel, as A B C D, Fig. 5.

23. A *Rectangle* is a parallelogram having four right angles, as A B C D, in Fig. 5.

24. A *Square* is an equilateral rectangle, having all its sides equal, like Fig. 5.

25. An *Oblong* is a rectangle whose adjacent sides are unequal, as the parallelogram shown at Fig. 10.

26. A *Rhombus* is an oblique-angled figure, or parallelogram having four equal sides, whose opposite angles only are equal, as C, Fig. 6.

27. A *Rhomboid* is an oblique-angled parallelogram, of which the adjoining sides are unequal, as D, Fig. 7.

28. A *Trapezium* is an irregular quadrilateral figure, having no two sides parallel, as E, Fig. 8.

29. A *Trapezoid* is a quadrilateral figure, which has two of its opposite sides parallel, and the remaining two neither parallel nor equal to one another, as F, Fig. 9.

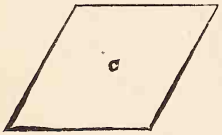


Fig. 6.

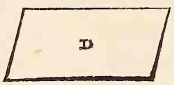


Fig. 7.

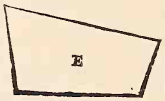


Fig. 8.

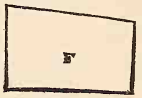


Fig. 9.

30. A *Diagonal* is a straight line drawn between two opposite angular points of a quadrilateral figure, or between any two angular points of a polygon. Should the figure be a parallelogram, the diagonal will divide it into two equal triangles, the opposite sides and angles of which will be equal to one another. Let A B C D, Fig. 10, be a parallelogram; join A C, then A C is a diagonal, and the triangles A D C, A B C, into which it divides the parallelogram, are equal.

31. A plane figure, bounded by more than four straight lines, is called a *Polygon*. A regular polygon has all its sides equal, and consequently its angles are also equal, as K, L, M, and N, Figs.

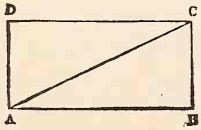


Fig. 10.

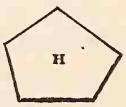


Fig. 11.

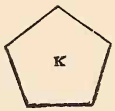


Fig. 12.

Fig. 13.

12–15. An irregular polygon has its sides and angles unequal, as H, Fig. 11. Polygons are named according to the number of their sides or angles, as follows:—

32. A *Pentagon* is a polygon of five sides, as H or K, Figs. 11, 12.

33. A *Hexagon* is a polygon of six sides, as L, Fig. 13.

34. A *Heptagon* has seven sides, as M. Fig. 14.

35. An *Octagon* has eight sides, as N, Fig. 15.

An *Enneagon* has nine, a *Decagon* ten, an *Undecagon* eleven, and a *Dodecagon* twelve sides. Figures having more than twelve sides are generally designated *Polygons*, or many-angled figures.

36. A *Circle* is a plane figure bounded by one uniformly curved line, *b c d* (Fig. 16), called the circumference, every part of which is equally distant from a point within it, called the centre, as *a*.

37. The *Radius* of a circle is a straight line drawn from the centre to the circumference; hence, all the radii (plural for radius) of the same circle are equal, as *b a*, *c a*, *e a*, *f a*, in Fig. 16.

38. The *Diameter* of a circle is a straight line drawn through the centre, and terminated on each side by the circumference; conse-

Fig. 14.

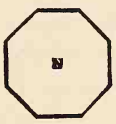


Fig. 15.

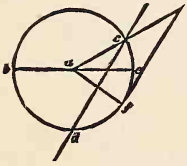


Fig. 16.

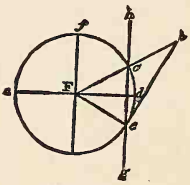


Fig. 17.

quently the diameter is exactly twice the length of the radius; and hence the radius is sometimes called the semi-diameter. (See *b a e*, Fig. 16.)

49. The *Chord* or *Subtens* of an arc is any straight line drawn from one point in the circumference of a circle to another, joining the extremities of the arc, and dividing the circle either into two equal, or two unequal parts. If into equal parts, the chord is also the diameter, and the space included between the arc and the diameter, on either side of it, is called a semicircle, as *b a e* in Fig. 16. If the parts cut off by the chord are unequal, each of them is called a *segment* of the circle. The same chord is therefore common to two arcs and two segments; but, unless when stated otherwise, it is always understood that the lesser arc or segment is spoken of, as in Fig. 16, the chord *c d* is the chord of the arc *c e d*.

If a straight line be drawn from the centre of a circle to meet the chord of an arc perpendicularly, as *a f*, in Fig. 16, it will divide the chord into two equal parts, and if the straight line be produced

to meet the arc, it will also divide it into two equal parts, as *c f, f d.*

Each half of the chord is called the sine of the half-arc to which it is opposite; and the line drawn from the centre to meet the chord perpendicularly, is called the co-sine of the half-arc. Consequently, the radius, the sine, and co-sine of an arc form a right angle.

40. Any line which cuts the circumference in two points, or a chord lengthened out so as to extend beyond the boundaries of the circle, such as *g h* in Fig. 17, is sometimes called a *Secant.* But, in trigonometry, the secant is a line drawn from the centre through one extremity of the arc, so as to meet the tangent which is drawn from the other extremity at right angles to the radius. Thus, F *c b* is the secant of the arc *c e*, or the angle *c* F *e*, in Fig. 17.

41. A *Tangent* is any straight line which touches the circumference of a circle in one point. which is called the point of contact, as in the tangent line *e b*, Fig. 17.

42. A *Sector* is the space included between any two radii, and that portion of the circumference comprised between them: *c e* F is a sector of the circle *a f c e*, Fig. 17.

43. A *Quadrant*, or quarter of a circle, is a sector bounded by two radii, forming a right angle at the centre, and having one-fourth part of the circumference for its arc, as F *f d*, Fig. 17.

44. An *Arc*, or *Arch*, is any portion of the circumference of a circle, as *c d e*, Fig. 17.

It may not be improper to remark here that the terms circle and circumference are frequently misapplied. Thus we say, describe a circle from a given point, etc., instead of saying describe the circumference of a circle—the circumference being the curved line thus described, everywhere equally distant from a point within it, called the centre; whereas the circle is properly the superficial space included within that circumference.

45. *Concentric Circles* are circles within circles, described from the same centre; consequently, their circumferences are parallel to one another, as Fig. 18.

46. *Eccentric Circles* are those which are not described from the

same centre; any point which is not the centre is also eccentric in reference to the circumference of that circle. Eccentric circles may also be tangent circles; that is, such as come in contact in one point only, as Fig. 19.

47. *Altitude.* The height of a triangle or other figure is called its *altitude.* To measure the altitude, let fall a straight line from the vertex, or highest point in the figure, perpendicular to the base or opposite side; or to the base continued, as at B D, Fig. 20, should the form of the figure require its extension. Thus C D is the altitude of the triangle A B C.

We have now described all the figures we shall require for the purpose of thoroughly understanding all that will follow in this book; but we would like to say right here that the student who has time should not stop at this point in the study of geometry, for the time spent in obtaining a thorough knowledge of this useful

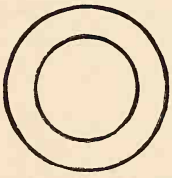


Fig. 18.

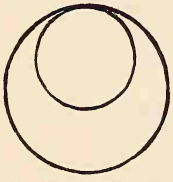


Fig. 19.

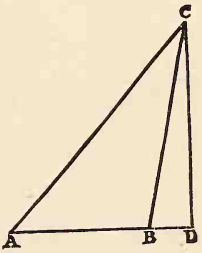


Fig. 20.

science will bring in better returns in enjoyment and money, than if expended for any other purpose.

We will now proceed to explain how the figures we have described can be constructed. There are several ways of constructing nearly every figure we produce, but we have chosen those methods that seemed to us the best, and to save space have given as few examples as possible consistent with efficiency.

PROBLEM I.—*Through a given point* C (Fig. 18 *a*), *to draw a straight line parallel to a given straight line* A B.

In A B (Fig. 18 *a*) take any point *d*, and from *d* as a centre with the radius *d* C, describe an arc C *e*, cutting A B in *e*, and from C as a

centre, with the same radius, describe the arc *d* D, make *d* D equal to C *e*, join C D, and it will be parallel to A B.

PROBLEM II.—*To make an angle equal to a given rectilineal angle.*

From a given point E (Fig. 19 *a*), upon the straight line E F, to make an angle equal to the given angle A B C. From the angular point B, with any radius, describe the arc *e f*, cutting B C and B A in the points *e* and *f*. From the point E on E F with the same radius,

Fig. 18 *a*.

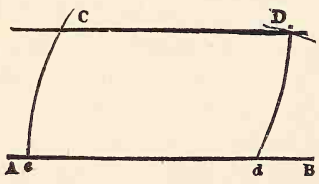
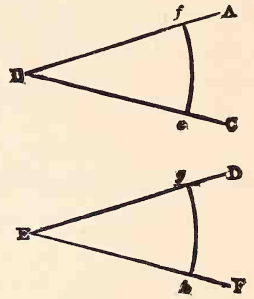


Fig. 19 *a*.



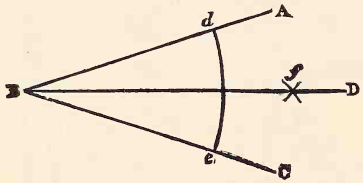


Fig. 20 *a*.

describe the arc *h g*, and make it equal to the arc *e f*; then from E, through *g*, draw the line E D: the angle D E F will be equal to the angle A B C.

PROBLEM III.—*To bisect a given angle.*

Let A B C (Fig. 20 *a*) be the given angle. From the angular point B, with any radius, describe an arc cutting B A and B C in the points *d* and *e*; also, from the points *d* and *e* as centres, with any radius greater than half the distance between them, describe arcs cutting each other in *f*; through the points of intersection *f*, draw B *f* D: the angle A B C is bisected by the straight line B D; that is, it is divided into two equal angles, A B D and C B D.

PROBLEM IV.—*To trisect or divide a right angle into three equal angles.*

Let A B C (Fig. 21) be the given right angle. From the angular

point B, with any radius, describe an arc cutting B A and B C in the points *d* and *g*; from the points *d* and *g*, with the radius B *d* or B *g*, describe the arcs cutting the arc *d g* in *e* and *f*; join B *e* and B *f*: these lines will trisect the angle A B C, or divide it into three equal angles.

The trisection of an angle can be effected by means of elementary geometry only in a very few cases; such, for instance, as those where the arc which measures the proposed angle is a whole circle, or a half, a fourth, or a fifth part of the circumference. Any angle of a pentagon is trisected by diagonals, drawn to its opposite angles.

PROBLEM V.—*From a given point* C, *in a given straight line* A B, *to erect a perpendicular.*

From the point C (Fig. 22), with any radius less than C A or C B, describe arcs cutting the given line A B in *d* and *e*; from these

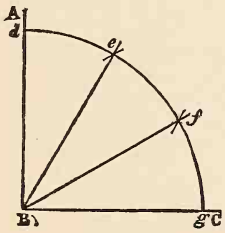


Fig. 21.

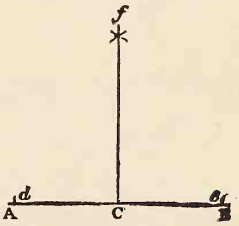


Fig. 22.

points as centres, with a radius greater than C *d* or C *e*, describe arcs intersecting each other in *f*: join C *f*, and this line will be the perpendicular required.

Another Method.—To draw a right angle or erect a perpendicular by means of any scale of equal parts, or standard measure of inches, feet, yards, etc., by setting off distances in proportion to the numbers 3, 4 and 5, or 6, 8 and 10, or any numbers whose squares correspond to the sides and hypothenuse of a right-angled triangle.

From any scale of equal parts, as that represented by the line D (Fig. 23), which contains 5, set off from B, on the line A B, the distance B *e*, equal to 3 of these parts; then from B, with a radius equal to 4 of the same parts, describe the arc *a b*; also from *e* as a

centre, with a radius equal to 5 parts, describe another arc intersecting the former in C; lastly join B C; the line B C will be perpendicular to A B.

This mode of drawing right angles is more troublesome upon paper than the method previously given; but in laying out grounds or foundations of buildings it is often very useful, since only with a ten-foot pole, tape line, or chain, perpendiculars may be set out very accurately. The method is demonstrated thus:—The square of the hypothenuse, or longest side of a right-angled triangle, being equal to the sum of the squares of the other two sides, the same property must always be inherent in any three numbers, of which

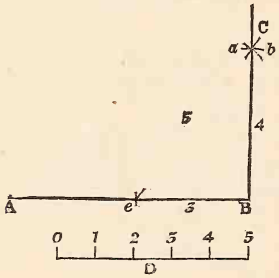


Fig. 23.

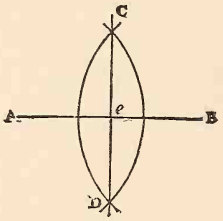


Fig. 24.

the squares of the two lesser numbers, added together, are equal to the square of the greater. For example, take the numbers 3, 4, and 5; the square of 3 is 9, and the square of 4 is 16; 16 and 9, added together make 25, which is 5 times 5, or the square of the greater number. Although these numbers, or any multiple of them, such as 6, 8, 10, or 12, 16, 20, etc., are the most simple, and most easily retained in the memory, yet there are other numbers, very different in proportion, which can be made to serve the same purpose. Let n denote any number; then $n^2 + 1$, $n^2 - 1$, and $2n$, will represent the hypothenuse, base, and perpendicular of a right-angled triangle. Suppose $n = 6$, then $n^2 + 1 = 37$, $n^2 - 1 = 35$, and $2n = 12$: hence, 37, 35, and 12 are the sides of a right-angled triangle. A knowledge of this problem will often prove of the greatest service to the workman.

PROBLEM VI.—*To bisect a given straight line.*

Let A B (Fig. 24) be the given straight line. From the extreme points A and B as centres, with any equal radii greater than half the length of A B, describe arcs cutting each other in C and D: a straight line drawn through the points of intersection C and D, will bisect the line A B in *e*.

PROBLEM VII.—*To divide a given line into any number of equal parts.*

Let A B (Fig. 25) be the given line to be divided into five equal parts. From the point A draw the straight line A C, forming any angle with A B. On the line A C, with any convenient opening of the compasses, set off five equal parts towards C; join the extreme

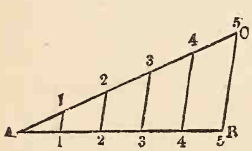


Fig. 25.

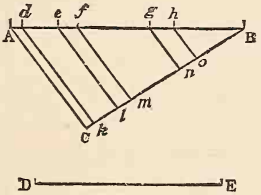


Fig. 26.

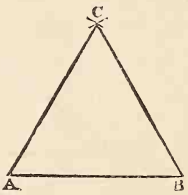


Fig. 27

points C B; through the remaining points 1, 2, 3, and 4, draw lines parallel to B C, cutting A B in the corresponding points, 1, 2, 3, and 4: A B will be divided into five equal parts, as required.

There are several other methods by which lines may be divided into equal parts; they are not necessary, however, for our purpose, so we will content ourselves with showing how this problem may be used for changing the scales of drawings whenever such change is desired. Let A B (Fig. 26) represent the length of one scale or drawing, divided into the given parts A *d*, *d e*, *e f*, *f g*, *g h*, and *h* B; and D E the length of another scale or drawing required to be divided into similar parts. From the point B draw a line B C = D E, and forming any angle with A B; join A C, and through the points *d*, *e*, *f*, *g*, and *h*, draw *d k*, *e l*, *f m*, *g n*, *h o*, parallel to A C; and the parts C *k*, *k l*, *l m*, etc., will be to each other, or to the whole line B C, as the lines A *d*, *d e*, *e f*, etc., are to each other, or to the given line or scale A B. By this method, as will be evident from

the figure, similar divisions can be obtained in lines of any given length.

PROBLEM VIII.—*To describe an equilateral triangle upon a given straight line.*

Let A B (Fig. 27) be the given straight line. From the points A and B, with a radius equal to A B, describe arcs intersecting each other in the point C. Join C A and C B, and A B C will be the equilateral triangle required.

PROBLEM IX.—*To construct a triangle whose sides shall be equal to three given lines*, F, E, D.

Draw A B (Fig. 28) equal to the given line F. From A as a centre, with a radius equal to the line E, describe an arc; then

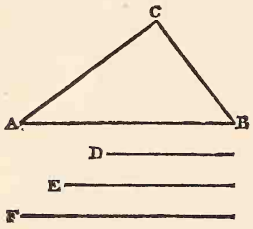


Fig. 28.

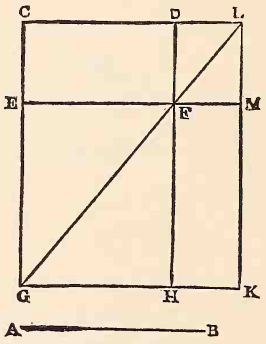


Fig. 29.

from B as a centre, with a radius equal to the line D, describe another arc intersecting the former in C; join C A and C B, and A B C will be the triangle required.

PROBLEM X.—*To describe a rectangle or parallelogram having one of its sides equal to a given line, and its area equal to that of a given rectangle.*

Let A B (Fig. 29) be the given line, and C D E F the given rectangle. Produce C E to G, making E G equal to A B; from G draw G K parallel to E F, and meeting D F produced in H. Draw the diagonal G F, extending it to meet C D produced in L; also draw L K parallel to D H, and produce E F till it meet L K in M; then F M K H is the rectangle required.

Equal and similar rhomboids or parallelograms of any dimensions may be drawn after the same manner, seeing the complements of the parallelograms which are described on or about the diagonal of any parallelogram, are always equal to each other; while the parallelograms themselves are always similar to each other, and to the original parallelogram about the diagonal of which they are constructed. Thus, in the parallelogram C G K L the complements C E F D and F M K H are always equal, while the parallelograms E F H G and D F M L about the diagonal G L, are always similar to each other, and to the whole parallelogram C G K L.

PROBLEM XI.—*To describe a square equal to two given squares.*

Let A and B (Fig. 30) be the given squares. Place them so that a side of each may form the right angle D C E; join D E, and upon this hypothenuse describe the square D E G F, and it will be equal to the sum of the squares A and B, which are constructed upon the legs of the right-angled triangle D C E. In the same manner, any other rectilineal figure, or even circle, may be found equal to the sum of other two similar figures or circles. Suppose the lines C D and C E to be the diameters of two circles, then D E will be the diameter of a third, equal in area to the other two circles. Or suppose C D and C E to be the like sides of any two similar figures, then D E will be the corresponding side of another similar figure equal to both the former.

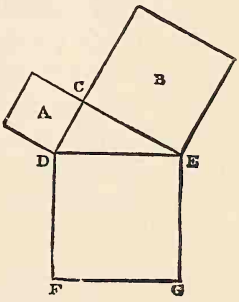


Fig. 30.

PROBLEM XII.—*To describe a square equal to any number of given squares.*

Let it be required to construct a square equal to the three given squares A, B, and C (Fig. 31). Take the line D E, equal to the side of the square C. From the extremity D erect D F perpendicular to D E, and equal to the side of the square B; join E F; then a square described upon this line will be equal to the sum of the two given squares C and B. Again, upon the straight line E F erect the per-

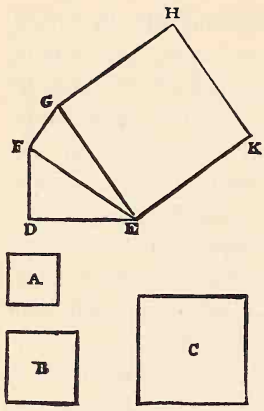


Fig. 31.

pendicular F G, equal to the side of the third given square A; and join G E, which will be the side of the square G E H K, equal in area to A, B, and C. Proceed in the same way for any number of given squares.

PROBLEM XIII.—*Upon a given straight line to describe a regular polygon.*

To produce a regular pentagon draw A B to C (Fig. 32), so that B C may be equal to A B; from B as a centre, with the radius B A or B C describe the semicircle A D C; divide the semi-circumference A D C into as many equal parts as there are parts in the required polygon, which, in the present case, will be five; through the second division from C draw the straight line B D, which will form another side of the figure. Bisect A B at *e*, and B D at *f*, and draw *e* G and *f* G perpendicular to A B and B D; then G, the point of intersection, is the centre of a circle, of which A B and D are points in the circumference. From G, with a radius equal to its distance from any of these points, describe the circumference A B D H K; then producing the dotted lines from the centre B, through the remaining divisions in the semicircle A D C, so as to meet the circumference of which G is the centre, in H and K, these points will divide the circle A B D H K into the number of parts required, each part being equal to the given side of the pentagon.

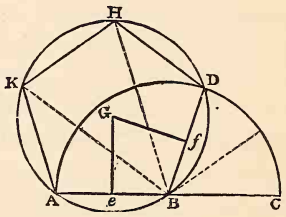


Fig. 32.

From the preceding example it is evident that polygons of any number of sides may be constructed upon the same principles, because the circumferences of all circles, when divided into the same number of equal parts, produce equal angles; and, consequently, by dividing the semi-circumference of any given circle into the

number of parts required, two of these parts will form an angle which will be subtended by its corresponding part of the whole circumference. And as all regular polygons can be inscribed in a circle, it must necessarily follow, that if a circle be described through three given angles of that polygon, it will contain the number of sides or angles required.

The above is a general rule, by which all regular polygons may be described upon a given straight line; but there are other methods by which many of them may be more expeditiously constructed, as shown in the following examples:—

PROBLEM XIV.—*Upon a given straight line to describe a regular pentagon.*

Let A B (Fig. 33) be the given straight line; from its extremity B erect B *c* perpendicular to A B, and equal to its half. Join A *c*, and produce it till *c d* be equal to B *c*, or half the given line A B. From A and B as centres, with a radius equal to B *d*, describe arcs intersecting each other in *e*, which will be the centre of the circumscribing circle A B F G H. The side A B applied successively to this circumference, will give the angular points of the pentagon; and these being connected by straight lines will complete the figure.

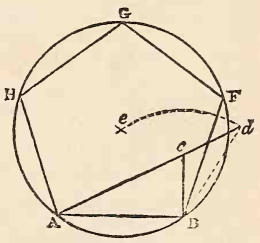


Fig. 33.

PROBLEM XV.—*Upon a given straight line to describe a regular hexagon.*

Let A B (Fig. 34) be the given straight line. From the extremities A and B as centres, with the radius A B describe arcs cutting each other in *g*. Again from *g*, the point of intersection, with the same radius, describe the circle A B C, which will contain the given side A B six times when applied to its circumference, and will be the hexagon required

PROBLEM XVI.—*To describe a regular octagon upon a given straight line.*

Let A B (Fig. 35) be the given line. From the extremities A and B erect the perpendiculars A E and B F; extend the given

line both ways to *k* and *l*, forming external right angles with the lines A E and B F. Bisect these external right angles, making each of the bisecting lines A H and B C equal to the given line A B. Draw H G and C D parallel to A E or B F, and each equal in length to A B. From G draw G E parallel to B C, and intersecting A E in E, and from D draw D F parallel to A H, intersecting B F in F. Join E F, and A B C D F E G H is the octagon required. Or from D

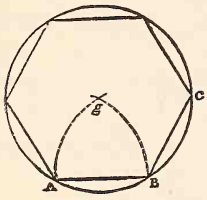


Fig 34.

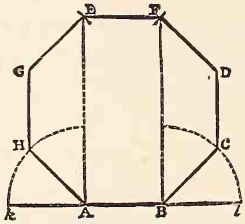


Fig. 35.

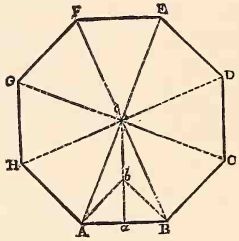


Fig. 36.

and G as centres, with the given line A B as radius, describe arcs cutting the perpendiculars A E and B F in E and F, and join G E, E F, F D, to complete the octagon.

Otherwise, thus.—Let A B (Fig. 36) be the given straight line on which the octagon is to be described. Bisect it in *a*, and draw the perpendicular *a b* equal to A *a* or B *a*. Join A *b*, and produce *a b* to *c*, making *b c* equal to A *b*; join also A *c* and B *c*, extending them so as to make *c* E and *c* F each equal to A *c* or B *c*. Through *c* draw C *c* G at right angles to A E. Again, through the same point *c*, draw D H at right angles to B F, making each of the lines *c* C, *c* D, *c* G, and *c* H equal to A *c* or *c* B, and consequently equal to one another. Lastly, join B C, C D, D E, E F, F G, G H, H A; A B C D E F G H will be a regular octagon described upon A B, as required.

PROBLEM XVII.—*In a given square to inscribe a given octagon.*

Let A B C D (Fig. 37) be the given square. Draw the diagonals A C and B D, intersecting each other in *e*; then from the angular points A B C and D as centres, with a radius equal to half the diagonal, viz., A *e* or C *e*, describe arcs cutting the sides of the

square in the points *f*, *g*, *h*, *k*, *l*, *m*, *n*, *o*, and the straight lines *o f*, *g h*, *k l*, and *m n*, joining these points will complete the octagon, and be inscribed in the square A B C D, as required.

PROBLEM XVIII.—*To find the area of any regular polygon.*

Let the given figure be a hexagon; it is required to find its area. Bisect any two adjacent angles, as those at A and B (Fig. 38), by the straight lines A C and B C, intersecting in C, which will be the

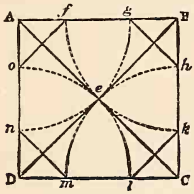


Fig. 37.

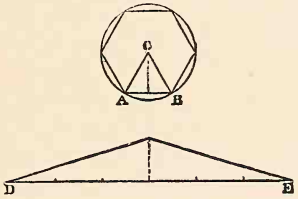


Fig. 38.

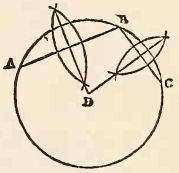


Fig. 39.

centre of the polygon. Mark the altitude of this elementary triangle by a dotted line drawn from C perpendicular to the base A B; then multiply together the base and altitude thus found, and this product by the number of sides: half gives the area of the whole figure.

Or otherwise, thus.—Draw the straight line D E, equal to six times, *i. e.*, as many times A B, the base of the elementary triangle, as there are sides in the given polygon. Upon D E describe an isosceles triangle, having the same altitude as A B C, the elementary triangle of the given polygon; the triangle thus constructed is equal in area to the given hexagon; consequently, by multiplying the base and altitude of this triangle together, half the product will be the area required. The rule may be expressed in other words, as follows:—The area of a regular polygon is equal to its perimeter, multiplied by half the radius of its inscribed circle, to which the sides of the polygon are tangents.

PROBLEM XIX.—*To describe the circumference of a circle through three given points.*

Let A, B, and C (Fig. 39) be the given points not in a straight line. Join A B and B C; bisect each of the straight lines A B and B C by perpendiculars meeting in D; then A, B and C are all equi-

distant from D; therefore a circle described from D, with the radius D A, D B, or D C, will pass through all the three points as required.

PROBLEM XX.—*To divide a given circle into any number of equal or proportional parts by concentric divisions.*

Let A B C (Fig. 40) be the given circle, to be divided into five equal parts. Draw the radius A D, and divide it into the same

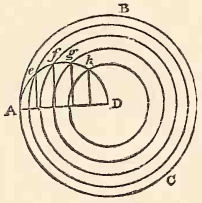


Fig. 40.

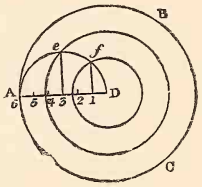


Fig. 41.

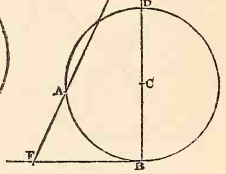


Fig. 42.

number of parts as those required in the circle; and upon the radius thus divided, describe a semicircle: then from each point of division on A D, erect perpendiculars to meet the semi-circumference in *e*, *f*, *g*, and *h*. From D, the centre of the given circle, with radii extending to each of the different points of intersection on the semicircle, describe successive circles, and they will divide the given circle into five parts of equal area as required; the centre part being also a circle, while the other four will be in the form of rings.

PROBLEM XXI.—*To divide a circle into three concentric parts, bearing to each other the proportion of one, two, three, from the centre.*

Draw the radius A D (Fig. 41), and divide it into six equal parts. Upon the radius thus divided, describe a semicircle: from the first and third points of division, draw perpendiculars to meet the semi-circumference in *e* and *f*. From D, the centre of the given circle, with radii extending to *e* and *f*, describe circles which will divide the given circle into three parts, bearing to each other the same proportion as the divisions on A D, which are as 1, 2 and 3. In like manner circles may be divided in any given ratio by concentric divisions.

PROBLEM XXII.—*To draw a straight line equal to any given arc of a circle.*

Let A B (Fig. 42) be the given arc. Find C the centre of the arc, and complete the circle A D B. Draw the diameter B D, and produce it to E, until D E be equal to C D. Join A E, and extend it so as to meet a tangent drawn from B in the point F; then B F will be nearly equal to the arc A B.

The following method of finding the length of an arc is equally simple and practical, and not less accurate than the one just given.

Let A B (Fig. 43) be the given arc. Find the centre C, and join A B, B C, and C A. Bisect the arc A B in D, and join also C D; then through the point D draw the straight line E D F, at right

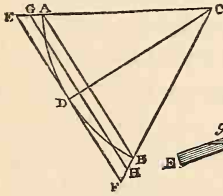


Fig. 43.

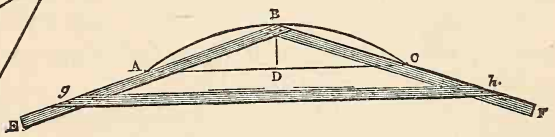


Fig. 44

angles to C D, and meeting C A and C B produced in E and F. Again, bisect the lines A E and B F in the points G and H. A straight line G H, joining these points, will be a very near approach to the length of the arc A B.

Seeing that in very small arcs the ratio of the chord to the double tangent or, which is the same thing, that of a side of the inscribed to a side of the circumscribing polygon, approaches to a ratio of equality, an arc may be taken so small, that its length shall differ from either of these sides by less than any assignable quantity; therefore, the arithmetical mean between the two must differ from the length of the arc itself by a quantity less than any that can be assigned. Consequently the smaller the given arc, the more nearly will the line found by the last method approximate to the exact length of the arc. If the given arc is above 60 degrees, or two-thirds of a quadrant, it ought to be bisected, and the length of the

semi-arc thus found being double, will give the length of the whole arc.

These problems are very useful in obtaining the lengths of veneers or other materials required for bending round soffits of door and window-heads.

PROBLEM XXIII.—*To describe the segment of a circle by means of two laths, the chord and versed sine being given.*

Take two rods, E B, B F (Fig. 44), each of which must be at least equal in length to the chord of the proposed segment A C: join them together at B, and expand them, so that their edges shall pass through the extremities of the chord, and the angle where they join shall be on the extremity B of the versed sine D B, or height of the segment. Fix the rods in that position by the cross piece *g h*, then by guiding the edges against pins in the extremities of the chord line A C, the curve A B C will be described by the point B.

PROBLEM XXIV.—*Having the chord and versed sine of the segment of a circle of large radius given, to find any number of points in the curve by means of intersecting lines.*

Let A C be the chord and D B the versed sine.

Through B (Fig. 45) draw E F indefinitely and parallel to A C; join A B, and draw A E at right angles to A B. Draw also A G at

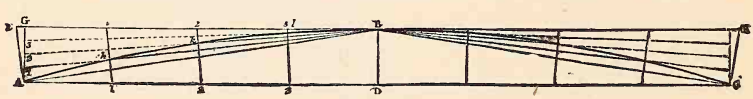


Fig. 45.

right angles to A C, or divide A D and E B into the same number of equal parts, and number the divisions from A and E respectively, and join the corresponding numbers by the lines 1 1, 2 2, 3 3. Divide also A G into the same number of equal parts as A D or E B, numbering the divisions from A upwards, 1, 2, 3, etc.; and from the points 1, 2 and 3, draw lines to B; and the points of intersection of these, with the other lines at *h*, *k*, *l*, will be points in the curve required. Same with B C.

Another Method.—Let A C (Fig. 46) be the chord and D B the versed sine. Join A B, B C, and through B draw E F parallel to A C.

From the centre B, with the radius B A or B C, describe the arcs A E, C F. and divide them into any number of equal parts, as 1, 2, 3: from the divisions 1, 2, 3, draw radii to the centre B, and divide each radius into the same number of equal parts as the arcs A E

Fig. 46.

and C F; and the points *g*, *h*, *l*, *m*, *n*, *o*, thus obtained, are points in the required curve.

These methods, though not absolutely correct, are sufficiently accurate when the segment is less than the quadrant of a circle.

PROBLEM XXV.—*To draw an ellipse with the trammel.*

The trammel is an instrument consisting of two principal parts, the fixed part in the form of a cross E F G H (Fig. 47), and the moveable piece or tracer *k l m*. The fixed piece is made of two rectangular bars or pieces of wood, of equal thickness, joined together so as to be in the same plane. On one side of the frame so formed, a groove is made, forming a right-angled cross. In the groove two studs, *k* and *l*, are fitted to slide freely, and carry attached to them the tracer *k l n*. The tracer is generally made to slide through a socket fixed to each stud, and provided with a screw or wedge, by which the distance apart of the studs may be regulated. The tracer has another slider *m*, also adjustable, which carries a pencil or point. The instrument is used as follows:—Let A C be the major, and H B the minor axis of an ellipse: lay the cross of the trammel on these lines, so that the centre lines of it may coincide with them; then adjust the sliders of the tracer, so that the distance between *k* and *m* may be equal to half the major axis, and the distance between *l* and *m* equal to half the minor

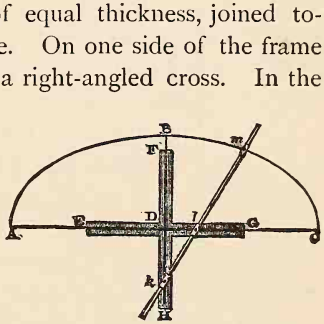


Fig. 47.

axis; then by moving the bar round, the pencil in the slider will describe the ellipse.

PROBLEM XXVI.—*An ellipse may also be described by means of a string.*

Let A B (Fig. 48) be the major axis, and D C the minor axis of the ellipse, and F G its two foci. Take a string E G F and pass it over the pins, and tie the ends together, so that when doubled it may be equal to the distance from the focus F to the end of the axis, B; then putting a pencil in the bight or doubling of the string at H and carrying it round, the curve may be traced. This is based on the well known property of the ellipse, that the sum of any two lines drawn from the foci to any points in the circumference is the same.

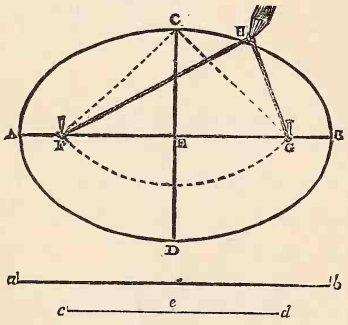


Fig. 48.

PROBLEM XXVII.—*The axes of an ellipse being given, to draw the curve by intersections.*

Let A C (Fig. 49) be the major axis, and D B half the minor axis. On the major axis construct the parallelogram A E F C, and make its height equal to D B. Divide A E and E B each into the same number of equal parts, and number the divisions from A and E respectively; then join A 1, 1 2, 2 3, etc., and their intersections will give points through which the curve may be drawn.

The points for a "raking" or rampant ellipse may also be found by the intersection of lines as shown at Fig. 50. Let A C be the major and E B the minor axis: draw A G and C H each parallel to B E, and equal to the semi-axis minor. Divide A D, the semi-axis major, and the lines A G and C H each into the same number of equal parts, in 1, 2, 3 and 4; then from E, through the divisions 1, 2, 3 and 4, on the semi-axis major A D, draw the lines E *h*, E *k*, E *l*, and E *m*; and from B, through the divisions 1, 2, 3 and 4 on the line A G, draw the lines 1, 2, 3 and 4 B; and the intersection of

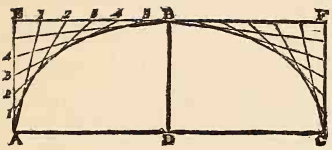


Fig. 49.

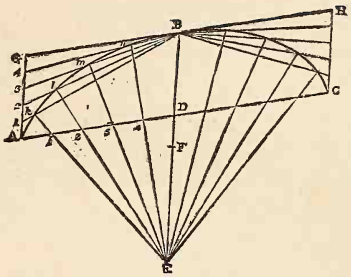


Fig. 50.

these with the lines E 1, 2, 3 and 4 in the points *h k l m*, will be points in the curve.

PROBLEM XXVIII.—*To describe with a compass a figure resembling the ellipse.*

Let A B (Fig. 51) be the given axis, which divide into three equal parts at the points *f g*. From these points as centres, with the radius *f* A, describe circles which intersect each other, and from the points of intersection through *f* and *g*, draw the diameters C *g* E, C *f* D. From C as a centre, with the radius C D, describe the arc D E, which

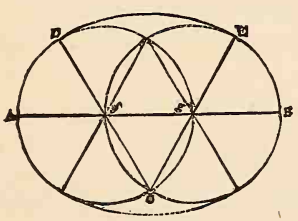


Fig. 51.

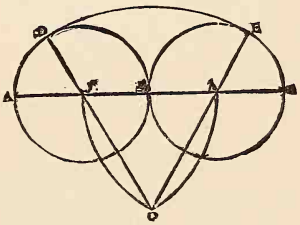


Fig. 52.

completes the semi-ellipse. The other half of the ellipse may be completed in the same manner, as shown by the dotted lines.

PROBLEM XXIX.—*Another method of describing a figure approaching the ellipse with a compass.*

The proportions of the ellipse may be varied by altering the ratio of the divisions of the diameter, as thus:—Divide the major axis of the ellipse A B (Fig. 52), into four equal parts, in the points *f g h*. On *f h* construct an equilateral triangle *f* C *h*, and produce

the sides of the triangle C *f*, C *h* indefinitely, as to D and E. Then from the centres *f* and *h*, with the radius A *f*, describe the circle A D *g*, B E *g*; and from the centre C, with the radius C D, describe the arc D E to complete the semi-ellipse. The other half may be completed in the same manner. By this method of construction the minor axis is to the major axis as 14 to 22.

PART II.—ARCHES, CENTRES, WINDOW AND DOOR HEADS.

IN order that the reader may be able to "lay out" and construct centres for arches, window and door heads, it is necessary he should have a clear conception of what an arch really is. For if a positive conclusion has not been arrived at, and if the "arch principle" is not fairly understood, he cannot be expected to design an arch, or to construct it with accuracy or intelligence, even if designed by another. Let us then state once for all, that every curved covering to an aperture is not necessarily an arch. Thus, the stone which rests on the piers shown in Fig. 53 is not an arch, being merely a stone hewn out in an arch-like shape; but at its top, the very point (A) at which strength is required, it is the weakest, and would fracture the moment any great weight were placed upon it.

Fig. 53.

It is not the province of this work to enter into a scientific disquisition on the arch, but some of its properties *must* be known to the mechanic before he will be able to construct centres understandingly; and the general principles here laid down will help the workman materially to form correct ideas concerning the work in hand. In all cases, however, we advise the student to arm himself with a thorough knowledge of the arch and the principles involved. Elementary works on the subject can be easily obtained, and all who would really study principles, and appreciate the exquisite refinement of the examples herein given, are strongly urged to read them.

The semi-circular arch shown at Fig. 54 is self-explanatory so far as the divisions are concerned. The under surface is called the *in*trados, and the outer the *ex*trados. The supports are called the

piers or abutments, though the latter term is one of more extensive application, referring more generally to the supports which bridges obtain from the shore on each side than to other arches. The term "piers" is, as a rule, supposed to imply supports which receive *vertical* pressure, whilst abutments are such as resist outward thrust. The upper parts of the supports on which an arch rests are called the imposts. The *span* of an arch is the complete width between the points where the intrados meets the imposts on either side; and a line connecting these points is called the "springing" or spanning line.

The separate wedge-like stones composing an arch are called Voussoirs, the central or uppermost one of which is called the Key-stone; whilst those next to the imposts are termed "springers."

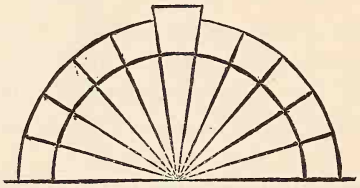


Fig. 54.

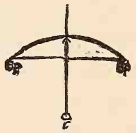


Fig. 55.

The highest point in the intrados is called the vertex or *crown*, and the height of this point above the springing line is termed the "rise" of the arch. It will be evident that in a semi-circular arch, such as Fig. 54, this would be the radius with which the semi-circle is struck. The spaces between the vertex and the springing line are called the flanks or haunches.

The following are the varieties of arches used:—

The *Semi-circular*, as shown in Fig. 54.

The *Segment* (Fig. 55), in which a portion only of the circle is used; the centre *c* is therefore *not* in the springing line Sp, Sp.

There are several other kind of arches besides the ones here described, but they are seldom made use of by the carpenter; there are the parabolic, hyperbolic, catenarian, and cycloidal. We have given the methods of describing the ellipse, which, next to the circle, is the most used in building.

The Semi-circular Arch was that principally used by the Romans, who employed it largely in their aqueducts and triumphal arches. The others are, however, mentioned by some writers as having been

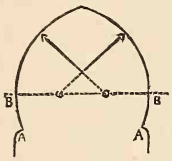


Fig. 56.

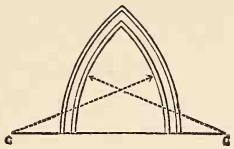


Fig. 57.

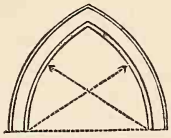


Fig. 58.

occasionally employed by the ancients. During the middle ages other forms were gradually introduced.

The Stilted Arch is an adaptation of the semi-circular arch, in which the springing line is raised above the top of the column, on a pedestal not much larger in diameter than the width of the voussoirs of the arch.

The Horse-shoe Arch.—This is almost restricted to the Arabian or Moorish style of architecture. In this form of arch the curve is carried below the line of centre or centres; for in some cases the arch is struck from one centre, and in others from two, as in Fig. 56.

Now it must not be supposed that the real bearing of the arch is at the impost A A; for if this were really so, it must be seen that any weight or pressure on the crown of the arch would cause it to break at B, but the fact is simply that the *real* bearings of the arch *are* at B B, and the prolongation of the arch beyond these points is merely a matter of form and has no structural significancy. The Horse-shoe arch belongs especially to the Mohammedan architecture, from its having originated with that faith, and from its having been used exclusively by its followers.

Next in point of time, but by far the most graceful in form, is the *pointed arch*, which is essentially the mediæval (or middle age) style, and is capable of almost endless variety. The origin of this form of arch has been the subject of much antiquarian discussion; but it is certain that although the pointed arch was first generally used in the architecture of the middle ages, recent discoveries have shown that it was used many centuries previously in Assyria.

The greater or less acuteness of the pointed arch depends on the position of the centres from which the flanks are struck.

The Lancet Arch.—This arch, Fig. 57, is constructed by placing the centres c c outside the span, but still on the same line with the imposts. This form of arch was first used in the Gothic, and as a rule indicates the style called "Early English."

Equilateral Arch.—Fig. 58 shows the Equilateral arch, the radius with which the arcs are struck being equal to the span of the arch, and the centres being the imposts; and thus, the crown and the imposts being united, an equilateral triangle is formed. This form was principally used in the "Decorated" period of Gothic architecture from about 1307 until about 1390, at which time the *Ogee* arch (Fig. 59) was also occasionally used.

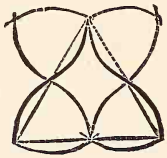


Fig. 59.

Fig. 60.

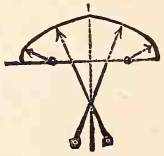


Fig. 61.

At a later date, during the existence of the "Perpendicular" style of Gothic architecture, viz., from the close of the 14th century to about 1630, we find various forms of arch introduced, such as the *Segmental* (Fig. 60), formed of segments of two circles, the centres of which are placed below the springing; and still later on we find the *Tudor*, or four-centred arch (Fig. 61), in which two of the centres are on the springing and two below it. The arches at the later period of this style became flatter and flatter, and this forms one of the features of Debased Gothic, when the beautiful and graceful forms of that style gradually decayed, and for a time were lost. Happily, in the present century there has been a gradual and spirited revival of the Gothic style, and works are now being produced which bid fair to rival in beauty of form and in principles of construction the marvellous buildings of the middle ages.

From the examples given, the workman will be able to lay out any of the usual arches required in building.

There are combinations, however, of these curves which the carpenter may be called upon to construct, such as the ones given herewith.

Fig. 62 is the elementary study upon which the subsequent figure is based.

Having drawn the circle, describe on the diameter two opposite semicircles, meeting at the centre, *a*.

Divine one of these into six equal parts, and set off one of these sixths from *i* to *n*.

Draw *a n*, and divide it into four equal parts. From the middle point of *a n* draw a line passing through the centre of the semi-

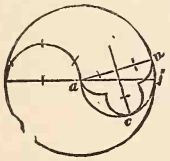


Fig. 62.

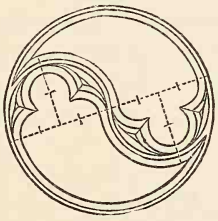


Fig. 63.

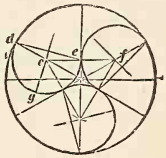


Fig. 64.

circle, and cutting it in *c*. From *c* set off on this line the length of one of the fourths of *a n*.

This point and the two in *a n* will be the centres for the interior curves.

Fig. 63 is the further working out of this elementary figure. It is desirable that a larger circle should be drawn. Then, when the figure has been carried up to the stage shown in the last, all the rest of the curves will be drawn from the same centres.

Fig. 64 is the elementary form of the tracery shown in Fig. 66.

We show the method of obtaining these curves in Fig. 67: At any point, as at A, draw a tangent, and A G at right angles to it. From A, with radius O A, cut the circle in B and C, and the tangent in the point F, using B as a centre. Bisect the angle B at F, and produce the bisecting line until it cuts A G in H. From O, with radius O H, cut the lines D C and E B in I and J. From H, I and J,

with radius H A, draw the three required circles, each of which should touch the other two and the outer circle.

Returning now to Fig. 64, having inscribed three equal circles in a circle, j ·· their centres, thus forming an equilateral triangle. From the centre of the surrounding circle draw radii passing through the angles of the triangle and cutting the circle in points; as *d* and two others. Draw *e d* and bisect it by *c g*; then the centres for the curves which are in the semicircle will be on the three lines *d c*, *c g* and *c e*.

These curves, in Gothic architecture, are called "foliations," or "featherings," and the points a which they meet are called "cusps." The completion of this study is shown at Fig. 66.

Fig. 65 shows the elementary construction f Fig. 68. Draw two diameters (Fig. 65) at right angles to each other, and join their extremities, thus inscribing a square in the circle. Bisect the quadrants by two diameters, cutting the sides of the square in the points,

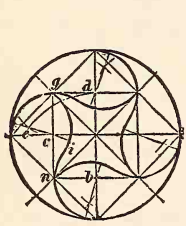


Fig. 65.

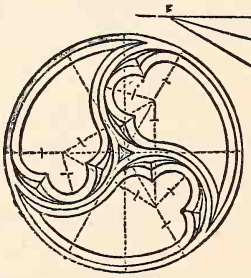


Fig. 66.

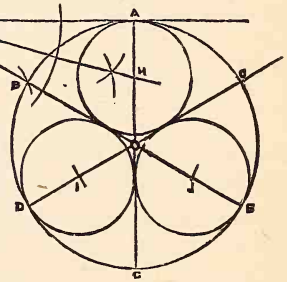


Fig. 67.

as *g*; join these points, and a second square will be inscribed within the first.

The middle points of the sides of this inner square, as *b c d*, are the centres of the arcs which start from the extremities of the diameters.

From *b*, with radius *b d*, describe an arc, and from *g*, with radius *g c*, describe another cutting the former one in *e*. Then *e* is the centre for the arc *i g*, which will meet the arc struck from *b*, in *i*. Of course, this process is to be carried on in each of the four lobes.

Fig. 68 is the completed figure. The method of drawing the foliation will have been suggested by Fig. 63, and is further shown in the present illustration.

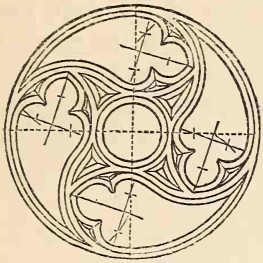


Fig. 68.

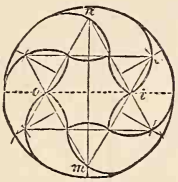


Fig. 69.

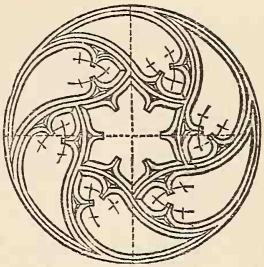


Fig. 70.

Fig. 69 shows the skeleton lines of Fig. 70. Divide the diameter into four equal parts, and on the middle two, as a common base, construct the two equilateral triangles *o i n* and *o i m*.

Draw lines through the middle points of the sides of the triangles, which, intersecting, will complete a six-pointed star in the circle, the angles of which will be the centres for the main lines of the tracery.

Fig. 70 is the completed figure.

The small figures, 71 and 72, will be understood without further instruction than is afforded by the examples.

Fig. 73 shows the construction of the tracery in a square panel.

Fig. 71.

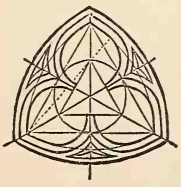


Fig. 72.

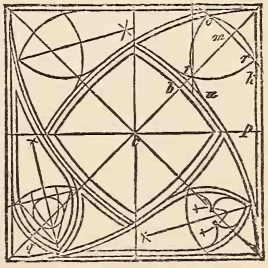


Fig. 73.

From each of the angles of the square (the inner one in this figure), with a radius equal to the length of the side of the square,

describe arcs; these intersecting will give a four-sided curvilinear figure in the centre. Draw diagonals in the square.

From the point where the diagonal intersects the curve *b* (the middle line of the three here shown) set off on the diagonal the length *c b*, viz., *b m*.

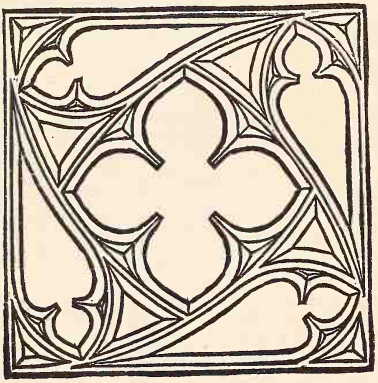


Fig. 74

From *q*, with radius *m q*, describe an arc cutting the original arc in *o*.

Make *m r* equal to *m o*.

From *o* and *r*, with radius *o r*, describe arcs intersecting each other in *i*: produce these until they meet the curve *p* in *n*.

The foliation and completion as per Fig. 74 will now be found simple.

PART III.—ROOFS.

PERHAPS the best way to "lay out" a common rafter is by using the "carpenter's steel square," and full directions for this purpose are given in a very complete work on "The Steel Square and its Uses," published by the Industrial Publication Company, New York City. As the present work is intended only to show the way the lengths and bevels can be obtained by lines, we shall not refer further to the use of the "square."

There are various kinds of roofs, some of them dependent for their shapes on the nature of the plan. The most simple form of a roof is the "leanto" or "shed-roof." The roof most in use is the "saddle-roof," which is formed by two sets of rafters and ridge pole;

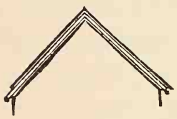


Fig. 75.

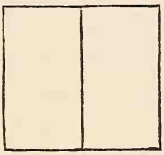


Fig. 76.

Fig. 77.

sometimes this is called a "peak-roof." Fig. 75 shows an elevation, and Fig. 76 a plan of this kind of a roof, while Figs. 77 and 78

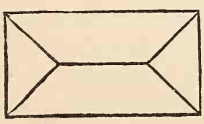


Fig. 78.

Fig. 79.

Fig. 80.

show the plan and elevation of a hip-roof. Figs. 79 and 80 show two views of a pyrimidal roof.

A few remarks on the principles involved in roof construction, before proceeding further, will not be out of place.

If A B, C B (Fig. 81 *a*) be two rafters, placed on walls at A and C, and meeting in a ridge B. Even by their own weight, and much more when loaded, these rafters would have a tendency to spread outwards at A and C, and to sink at B. If this tendency be restrained by a tie established betwixt A and C, and if A B, B C be perfectly rigid, and the tie A C incapable of extension, B will become a fixed point. This, then, is the ordinary couple-roof, in which the tie A C is a third piece of timber; and which may be used for spans of limited extent; but when the span is so great that the tie A C tends to bend downwards or sag, by reason of its length, then the conditions of stability obviously become impaired. Now, if from the point B a string or tie be let down and attached to the middle D, of A C, it will evidently be impossible for A C to bend downwards so long as A B, B C remain of the same length: D, therefore, like B, will become a fixed point, if the tie B D be incapable of extension. But the span may be increased, or the size of the rafters A B, C B be diminished, until the latter also have a tendency to sag; and to prevent this, pieces D E, D F are introduced, extending from the fixed point D to the middle of each rafter, and establishing F and E as fixed points also, so long as D E, D F remain unaltered in length. Adopting the ordinary meaning of the verb "to truss," as expressing to tie up (and there seems to be no reason why we should seek further for the etymology), we truss or tie up the point D, and the frame A B C is a trussed frame. In like manner, F being established as a fixed point, G is trussed to it.

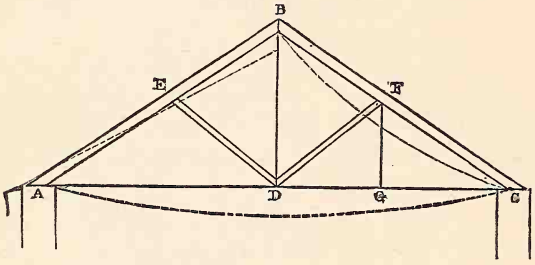


Fig. 81 *a*.

In every trussed frame there must obviously be one series of the component parts in a state of compression, and the other in a state of extension. The functions of the former can only be filled by pieces which are rigid, while the place of the latter may be supplied by strings. In the diagram, the pieces A B, C B are compressed, and A C, D B are extended; yet in general the tie D B is called a *king*-post, a term which conveys an altogether erroneous idea of its duties. Thus we see how the two principal rafters, by their being incapable of compression, and the tie-beam by its being incapable of extension, serve, through the means of the king-post, to establish a fixed point in the centre of the void spanned by the roof, which again becomes the *point d'appui* of the struts, which at the same time prevent the rafters from bending, and serve in the establishing of other fixed points; and the combination of these pieces is called a king-post roof.

It is sometimes, however, inconvenient to have the centre of the space occupied by the king-post, especially where it is necessary to have apartments in the roof. In such a case recourse is had to a different manner of trussing. Two suspending posts are used, and a fourth element is introduced, namely, the *straining beam a b* (Fig. 82 *b*), extending between the posts. The principle of trussing

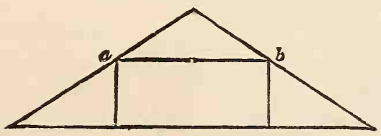


Fig. 82 *b*.

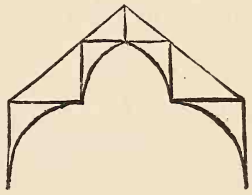


Fig 83 *c*.

is the same. The rafters are compressed, the straining beam is compressed, and the tie-beam and posts, the latter now called *queen-posts*, are in a state of tension.

In some roofs, for the sake of effect, the tie-beam does not stretch across between the feet of the principals, but is interrupted. In point of fact, although occupying the place of, it does not fill

the office of a tie-beam, but acts merely as a bracket attached to the wall (Fig. 83 *c*). It is then called a *hammer-beam.*

It is a general rule that wood should be used as struts and iron as ties; and in many modern trusses this rule has been admirably exemplified by the combination of both materials in the frames.

There is another class of principals in which tie-beams are not used. Such are the curved principals of De Lorme and Emy. In the system of Philibert de Lorme, arcs formed of small scantlings of timber are substituted for the framed principals; and in that of Colonel Emy, laminated arcs are used.

The principals of roofs may therefore, in respect of their construction, be divided broadly into two classes—First, those with tie-beams; and, second, those without tie-beams.

The first class, those with tie-beams, may be further classified as king-post roofs and queen-post roofs.

The second class may be arranged as follows:—

1st. Hammer-beam roofs.

2d. Curved principal roofs.

Having now given such hints regarding the principles of roof construction as will enable the workman to build any ordinary roof intelligently, we proceed to describe the methods of construction.

The lengths and bevels for rafters suitable for a roof similar to that shown in Fig. 75, are easily obtained, but the lines required

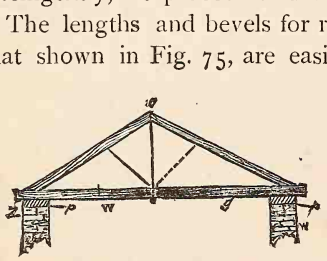


Fig. 81.

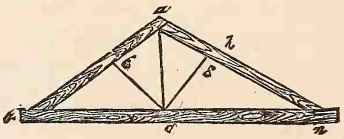


Fig. 82.

for a full development of the hip-roof shown at Fig. 79, necessarily demands considerable skill and knowledge on the part of the workman, as will be shown hereafter.

In Fig. 81 we show a roof that is at once strong and cheap for spans from 20 to 30 feet. *p p* shows the wall plates, *w* the wall,

o the ridge and head of suspending rod; w and *g* show where suspending rods may be placed if the span exceeds 25 feet.

Fig. 82 shows a roof with unequal sides. *a c* shows the suspending rod. *e e* may be braces of wood or rods of iron; *b* and *n* are resting points. This is suitable for a span from 20 to 30 feet.

Fig. 83 is suitable for a roof with a deck, and where the span is not more than 25 feet. It is also suitable for a small bridge crossing a creek, where the span is not more than from 16 to 22 feet.

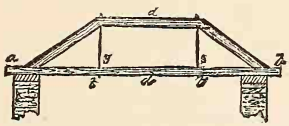


Fig. 83.

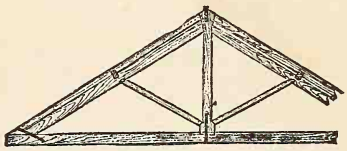


Fig. 84.

The deck is shown at *d*; *g t*, *s t* show the suspending rods; *a b* show projections for gutters and ease-offs.

Figs. 84 and 85 show two schemes for timber roofs. 84 will carry a span of 24 feet, and 85 will answer very well for a 30 feet span.

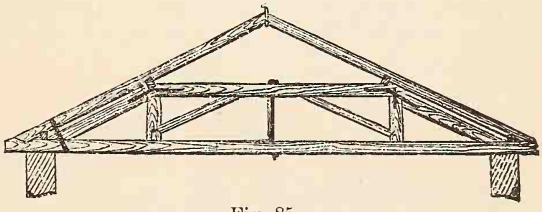


Fig. 85.

Fig. 86 shows a design suitable for a roof or a bridge. If used as a bridge it must be braced herring-bone style, as shown by the dotted lines. The arch is laminated; that is, formed of thin pieces of timber bolted together. It is suitable for a span of from 20 to 30 feet.

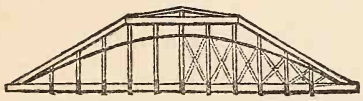


Fig. 86.

Fig. 87 is a more pretentious roof than any of the foregoing. It is a queen-post roof with an iron king-bolt, intended for a span of 32 feet.

A, is the principal rafter, 5 x 11 inches.
B, straining beam, 5 x 11 "
C, queen-post, 5 x 9 "
Struts, 4 x 5 "

c is the king-bolt, and may be 1½ or 1¾ inches in diameter. The common rafters may be 3 x 8 inches, and project over the walls

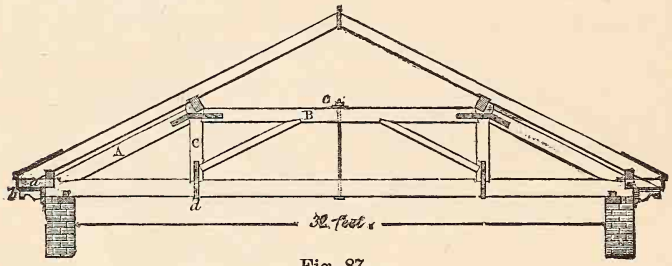


Fig. 87.

to form the cornice; *a* is a short ceiling-joist of the cornice; *b* is an ornamental bracket.

The roof shown at Fig. 88 is one of the best styles of a queen-post roof; it is for a span of 40 feet. The following explanations

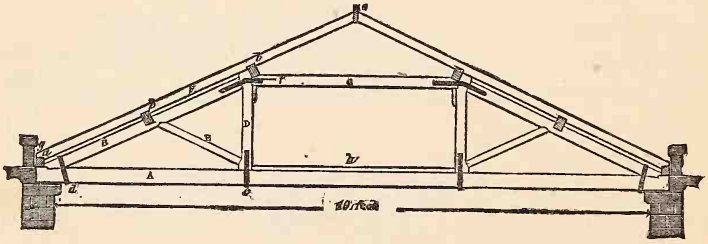


Fig. 88.

and sizes of stuff may serve to aid the workman in designing other similar roofs:

A, tie-beam or chord, 6 x 12 inches.
B, principal rafter, 6 x 10 "
C, straining beam, 6 x 9 "
D, queen-post, 6 x 8 "

E, strut, 6 x 6 inches.
F, common rafter, 6 x $2\frac{1}{2}$ "
a, wall-plate, 6 x 9 "
b, purlin, 9 x 12 "

c, ridge-pole; *d*, strap at foot of common rafters; *e*, strap at foot of queen-post; *f*, strap at head of queen-post; *h*, straining sill.

Fig. 89 shows a roof suitable for a span of 60 feet. It has king-post, queen-post, principal, tie-beam, common rafters, purlins and struts.

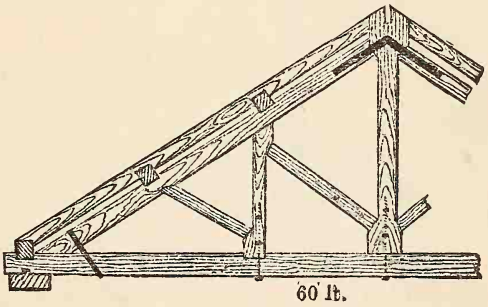


Fig. 89.

Figs. 90 and 91 are combination roofs, and may be thrown over spans from 75 to 100 feet. One is designed for a church roof, and the other for covering a theatre.

Fig. 92 shows a scheme for a mansard roof. This will be found to be an excellent design where the span is not more than 32 feet.

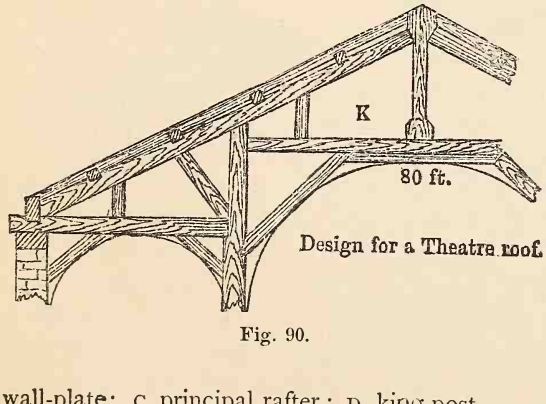


Fig. 90.

Fig. 93 is a perspective view of a king-post roof with all the various pieces lettered for reference: A, tie-beam; B, wall-plate; C, principal rafter; D, king-post.

Fig. 94 shows a perspective view of a queen-post roof with refer-

ence letters: A, tie-beam. B, queen-posts. C, collar-beam. D, strut. E, purlin. F, wall-plate. G, common rafters. H, ridge-pole.

A sufficient number of examples for timber roofs of the ordinary kind have been shown to enable the intelligent workman to design and construct any roof he may be called upon to execute.

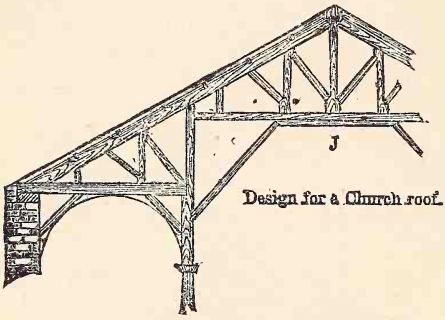


Fig. 91.

Before discussing hip-roofs, it will be in order to give the reader Mr. Tredgold's rules for determining the sizes of the various timbers for the style of roof exhibited. It must be borne in mind, however, that the rules given are empirical, and too general to be relied on, except in simple cases. It is always best to follow general usage in the adoption of sizes of timber when designing roofs of an unusual shape or character.

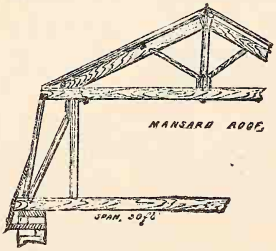


Fig. 92.

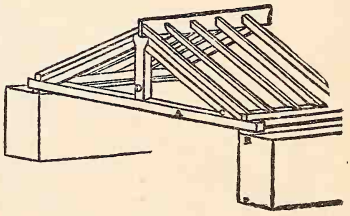


Fig. 93.

In estimating the pressure on a roof, for the purpose of apportioning the proper sizes of timber to be used, not only the weight of the timber and the slates, or other covering, must be taken, but also the weight of snow which in severe climates may be on its surface, and also the force of the wind, which we may calculate at 40 lbs. per superficial foot.

The weight of the covering materials, and the slope of roof, which is usually given, are contained in the following table :—

Material.	Inclination.	Weight on a Square Foot.
Tin	Rise 1 inch to a foot.	$\frac{5}{8}$ to $1\frac{1}{4}$ lbs.
Copper	" 1 " "	1 " $1\frac{1}{2}$ "
Lead	" 2 " "	4 " 7 "
Zinc	" 3 " "	$1\frac{1}{4}$ " 2 "
Short pine shingles	" 5 " "	$1\frac{1}{2}$ " $2\frac{1}{2}$ "
Long cypress shingles	" 6 " "	4 " 5 "
Slate	" 6 " "	5 " 9 "

With the aid of this table, and taking into account the pressure of the wind and the weight of snow, the strength of the different parts may be calculated from the following empirical rules, which were deduced by Mr. Tredgold from experience. They are easy of application, and useful for simple cases. Mr. Tredgold assumes $66\frac{1}{2}$ lbs. as the weight on each sq. ft.

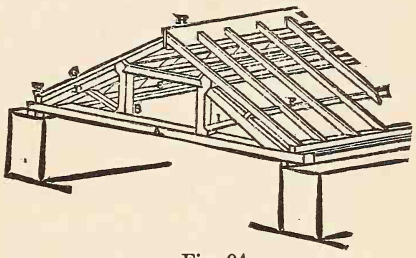


Fig. 94.

It is customary to make the rafters, tie-beams, posts and struts all of the same thickness.

IN A KING-POST ROOF OF PINE TIMBER.

To find the dimensions of the principal rafters.

Rule.—Multiply the square of the length in feet by the span in feet, and divide the product by the cube of the thickness in inches; then multiply the quotient by 0·96 to obtain the depth in inches.

Mr. Tredgold gives also the following rule for the rafters, as more general and reliable :—

Multiply the square of the span in feet by the distance between the principals in feet, and divide the product by 60 times the rise in feet: the quotient will be the area of the section of the rafter in ins.

If the rise is one-fourth of the span, multiply the span by the distance between the principals, and divide by 15 for the area of section.

When the distance between the principals is 10 feet, the area of section is two-thirds of the span.

To find the dimensions of the tie-beam, when it has to support a ceiling only.

Rule.—Divide the length of the longest unsupported part by the cube root of the breadth, and the quotient multiplied by 1·47 will give the depth in inches.

To find the dimensions of the king-post.

Rule.—Multiply the length of the post in feet by the span in feet: multiply the product by 0·12, which will give the area of the section of the post in inches. Divide this by the breadth for the thickness, or by the thickness for the breadth.

To find the dimensions of struts.

Rule.—Multiply the square root of the length supported, in feet, by the length of the strut in feet, and the square root of the product multiplied by 0·8 will give the depth, which multiplied by 0·6 will give the thickness.

IN A QUEEN-POST ROOF.

To find the dimensions of the principal rafters.

Rule.—Multiply the square of the length in feet by the span in feet, and divide the product by the cube of the thickness in inches: the quotient multiplied by 0.155 will give the depth.

To find the dimensions of the tie-beam.

Rule.—Divide the length of the longest unsupported part by the cube root of the breadth, and the quotient multiplied by 1·47 will give the depth.

To find the dimensions of the queen-posts.

Rule.—Multiply the length in feet of the post by the length in feet of that part of the tie-beam it supports: the product multiplied by 0·27 will give the area of the post in inches; and the breadth and thickness can be found as in the king-post.

The dimensions of the struts are found as before.

To find the dimensions of a straining-beam.

Rule.—Multiply the square root of the span in feet by the length of the straining-beam in feet, and extract the square root of the

product: multiply the result by 0·9, which will give the depth in inches. The beam, to have the greatest strength, should have its depth to its breadth in the ratio of 10 to 7; therefore, to find the breadth, multiply the depth by 0·7.

To find the dimensions of purlins.

Rule.—Multiply the cube of the length of the purlin in feet by the distance the purlins are apart in feet, and the fourth root of the product will give the depth in inches, and the depth multiplied by 0·6 will give the thickness.

To find the dimensions of the common rafters when they are placed 12 inches apart.

Rule.—Divide the length of bearing in feet by the cube root of the breadth in inches, and the quotient multiplied by 0·72 will give the depth in inches.

Beams acting as struts should not be cut into or mortised on one side, so as to cause lateral yielding.

Purlins should never be framed into the principal rafters, but should be notched. When notched, they will carry nearly twice as much as when framed.

Purlins should be in as long pieces as possible.

Rafters laid horizontally are very good in construction, and cost less than purlins and common rafters.

The ends of tie-beams should be kept with a free space round them, to prevent decay. It is said that girders of oak in the Chateau Roque d'Ondres, and girders of fir in the ancient Benedictine monastery at Bayonne, France, which had their ends in the wall wrapped round with plates of cork, were found sound, while those not so protected were rotten and worm-eaten.

It is an injudicious practice to give an excessive camber to the tie-beam: it should only be drawn up when deflected, as the parts come to their bearings.

The struts should always be immediately underneath that part of the rafter whereon the purlin lies.

The diagonal joints of struts should be left a little open at the inner part, to allow for the shrinkage of the heads and feet of the king and queen-posts.

It should be specially observed that all cranks or bends in iron ties are avoided.

And, as an important final maxim—*Every construction should be a little stronger than strong enough.*

METHODS OF DEVELOPING HIP-ROOFS.*

The principles to be determined in a hip-roof are seven; namely:

1st. The angle which a common rafter makes with the level of the top of the building; that is, the pitch of the roof.

2nd. The angle which the hip-rafter makes with the level of the building.

3d. The angles which the hip-rafter makes with the adjoining sides of the roof. This is called the backing of the hip.

4th. The height of the roof, or the "rise," as it is called.

5th. The lengths of the common rafters.

6th. The lengths of the hip-rafters.

7th. The distance between the centre line of the hip-rafter and the centre line of the first entire common rafter.

The first, fourth, fifth and seventh are generally given, and from these the others may be found, as will be shown by the following

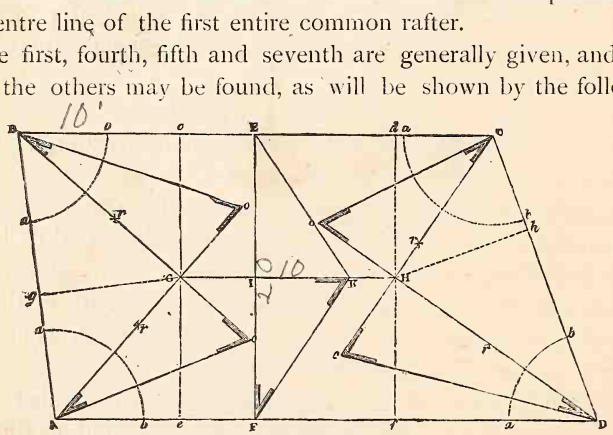


Fig. 95.

illustrations: Let A B C D Fig. 95, be the plan of a roof. Draw G H parallel to the sides, A D, B C, and in the middle of the distance between them. From the points A, B, C, D, with any radius, describe the curves *a b*, *a b*, cutting the sides of the plan at *a*, *b*. From

* Taken from "The Steel Square and Its Uses"

these points with any radius, bisect the four angles of the plan at *r*, *r*, *r*, *r*, and from A, B, C, D, through the points, *r*, *r*, *r*, *r*, draw the lines of the hip-rafters, A G, B G, C H, D H, cutting the ridge-line, G H, in G and H, and produce them indefinitely. The cross lines, *c e*, *d f*, are the seats of the last entire common rafters. Through any point in the ridge-line, I, draw E I F at right angles to G H. Make I K equal to the height or rise of roof, and join E K, F K; then E K is the length of a common rafter. Make G *o*, H *o*, equal to I K, the rise of the roof, and join A *o*, B *o*, C *o*, D *o*, for the length of the hip-rafters. If the triangles, A *o* G, B *o* G, be turned round their seats, A G, B G, until their perpendiculars are perpendicular to the plane of the plan, the points, o o, and the lines, G *o*, G *o*, will coincide, and the rafters, A *o*, B *o*, be in their true positions.

If the roof is irregular, and it is required to keep the ridge level, we proceed as shown in Fig. 96.

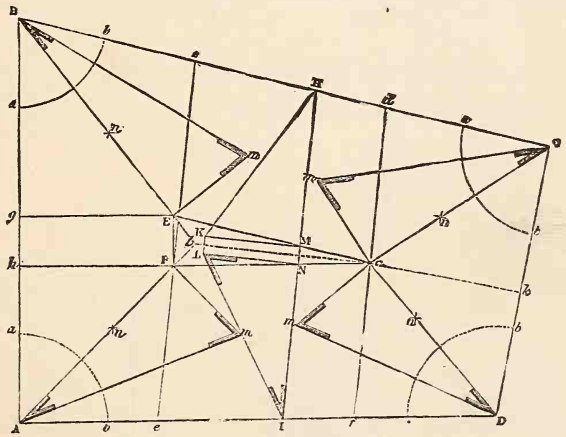


Fig. 96.

Bisect the angles of two ends by the lines A *b*, B *b*, C G, D G, in the same manner as in Fig. 95; and through G draw the lines G E, G F, parallel to the sides, C B, D A, respectively cutting A *b*, B *b*, in E and F; join E F; then the triangle, E G F, is a flat, and the remaining triangle and trapeziums are the inclined sides. Join G *b*, and draw H I perpendicular to it; at the points M and N, where H I cuts the

lines G E, G F, draw M K, N L perpendicular to H I, and make them equal to the rise; then draw H K, I L for the lengths of the common rafters. At E, set up E *m* perpendicular to B E; make it equal to M K or N L, and join B *m* for the length of the hip-rafter, and proceed in the same manner to obtain A *m*, C *m*, D *m*.

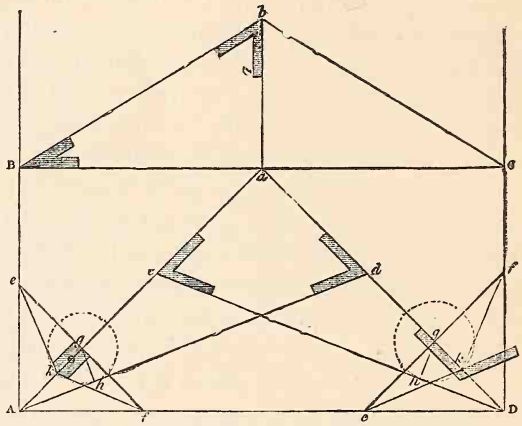


Fig. 97.

To find the backing of a hip-rafter, when the plan is right-angled, we proceed as shown in Fig. 97. Let B *b*, *b* C be the common rafters, A D the width of the roof, and A B equal to one half the width. Bisect B C in *a*, and join A *a*, D *a*. From *a* set off *a c*, *a d* equal to the height of the roof *a b*, and join A *d*, D *c*; then A *d*, D *c*, are the hip-rafters. To find the backing from any point *h* in A *d*, draw

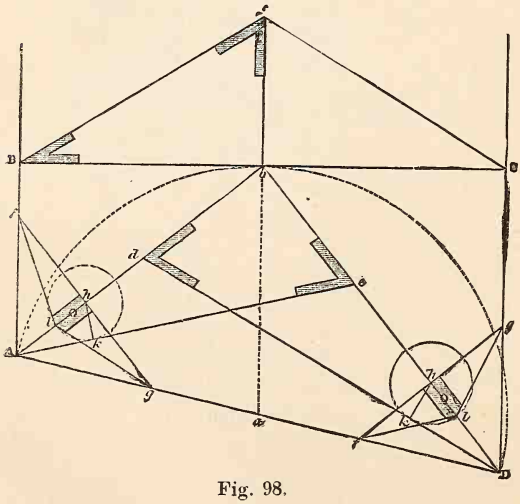


Fig. 98.

the perpendicular *h g*, cutting A *a* in *g*; and through *g* draw perpendicular to A *a* the line *e f*, cutting A B, A D in *e* and *f*. Make *g k* equal to *g h*, and join *k e*, *k f*; the angle *e k f* is the angle of the backing of the hip-rafter C.

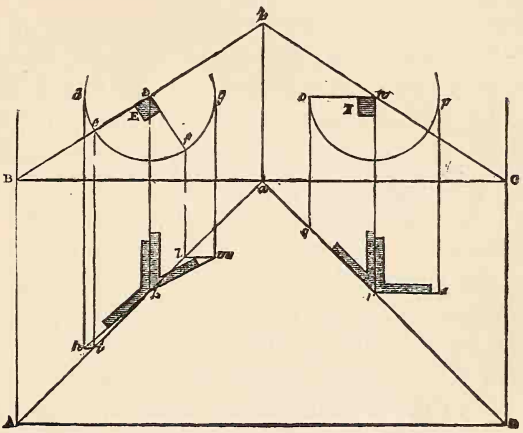


Fig. 99.

Fig. 98 shows the method of obtaining the backing of the hip where the plan is not right angled.

Bisect A D in *a*, and from *a* describe the semicircle A *b* D; draw *a b* parallel to the sides A B, D C, and join A *b*, D *b*, for the seat of the hip-rafters. From *b* set off on *b* A, *b* D the lengths *b d*, *b e*, equal to the height of the roof *b c*, and join A *e*, D *d*, for the lengths of the hip-rafters. To find the backing of the rafter:—In A *e*, take any point *k*, and draw *k h* perpendicular to A *e*. Through *h* draw *f h g* per-

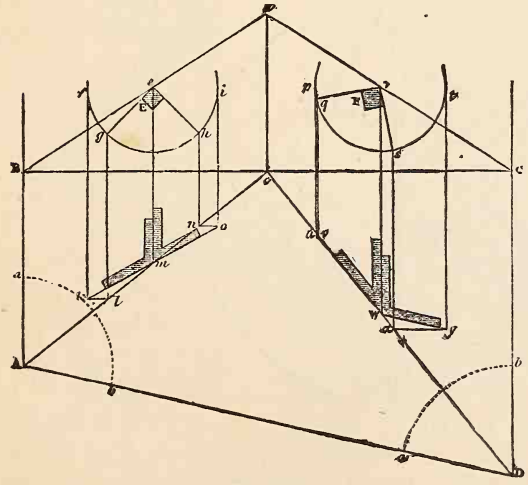


Fig. 100.

pendicular to A *b*, meeting A B, A D in *f* and *g*. Make *h l* equal to *h k*, and join *f l*, *g l*; then *f l*, *g l* is the backing of the hip.

Fig. 99 shows how to find the shoulder of purlins:

First, where the purlin has one of its faces in the plane of the roof, as at E. From *c* as a centre, with any radius, describe the arc *d g*; and from the opposite extremities of the diameter, draw *d h*, *g m*, perpendicular to B C. From *e* and *f*, where the upper adjacent sides of the purlin produced cut the curve, draw *e i*, *f l* parallel to *d h*, *g m*; also draw *c k* parallel to *d h*. From *l* and *i* draw *l m* and *i h* parallel to B C, and join *k h*, *k m*. Then *c k m*, is the down bevel of the purlin, and *c k h* is its side bevel.

When the purlin has two of its sides parallel to the horizon, it is worked out as shown at F. It requires no further explanation.

When the sides of the purlin make various angles with the horizon. Fig. 100 shows the application of the method described in Fig. 99 to these cases.

It sometimes happens, particularly in railroad buildings, that the carpenter is called upon to pierce a circular or conical roof with a saddle roof, and to accomplish this economically is often the result of much labor and perplexity if a correct method is not at hand.

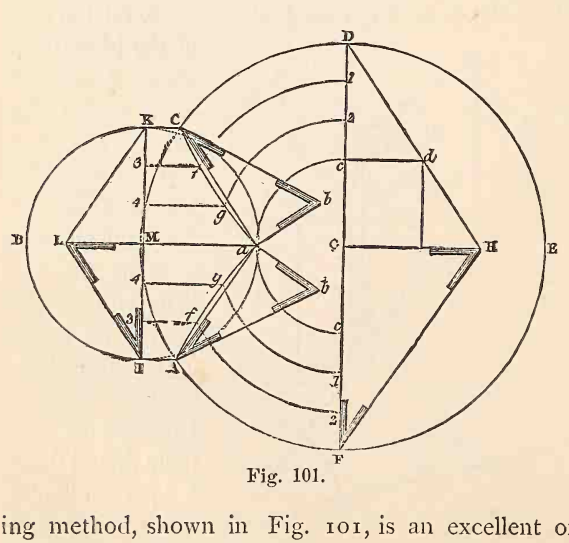


Fig. 101.

The following method, shown in Fig. 101, is an excellent one, and will no doubt be found useful in cases such as mentioned.

Let D H, F H be the common rafters of the conical roof, and K L, I L the common rafters of the smaller roof, both of the same pitch. On G H set up G *e* equal to M L, the height of the lesser roof, and draw *e d* parallel to D F, and from *d* draw *c d* perpendicular to D F. The triangle D *d c*, will then by construction be equal to the triangle K L M, and will give the seat and the length and pitch of the common rafter of the smaller roof B. Divide the lines of the seats in both figures, D *c*, K M, into the same number of equal parts; and through the points of division in E, from G as a centre, describe the curves *c a*, 2 *g*, 1 *f*, and through those in B, draw the lines 3 *f*, 4 *g*, M *a*, parallel to the sides of the roof, and intersecting the curves in *f g a*. Through these points trace the curves C *f g a*, A *f g a*, which give the lines of intersection of the two roofs. Then to find the valley rafters, join C *a*, A *a*; and on *a* erect the lines *a b*, *a b* perpendicular to C *a* and A *a*, and make them respectively equal to M L; then C *b*, A *b* is the length of the valley rafter, very nearly.

Fig. 102 shows how a curved hip-rafter may be obtained. The

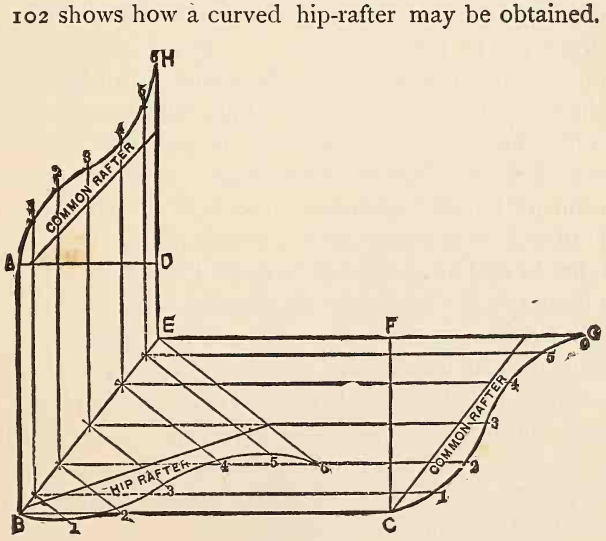


Fig. 102.

rafter shown in this instance is ogee in shape, but it makes no difference what shape the common rafter may be, the proper shape

and length of hip may be obtained by this method. It will be noticed that one side of the example shown is wider than the other; this is to show that the rule will work correctly where the sides are unequal in width, as well as where they are equal. Let A B C F E C represent the plan of the roof, F C G the profile of the wide side of the rafter. First, divide this rafter, G C, into any number of parts—in this case six. Transfer these points to the mitre line E B, or what is the same, the line in the plan representing the hip-rafter. From the points thus established in E B, erect perpendiculars indefinitely. With the dividers take the distance from the points in the line F C, measuring to the points in the profile G C, and set the same off on corresponding lines, measuring from E B, thus establishing the points 1, 2, 3, etc.; then a line traced through these points will be the required hip-rafter.

For the common rafter on the narrow side, continue the lines from E B parallel with the lines of the plan D E and A B. Draw A D at right angles to these lines. With the dividers as before, measuring from F C to the points in G C, set off corresponding distances from A D, thus establishing the points shown between A and H. A line traced through the points thus obtained will be the line of the rafter on the narrow side. This is supposed to be the return roof of a veranda, but is only shown as an example, for it is not customary to build verandas nowadays with an ogee roof, but with a rafter having a depression or cove in it. For accuracy it would be as well to make nearly twice the number of divisions shown from 1 to 6, as are there represented.

Fig. 103 shows a section of a Mansard roof with concave sides, and the manner of framing the same when it is to be erected on a brick or stone building. P *c* is the wall; *c* the wall-plate; A B the floor-joist; *h i* is the side rafter; *a i e* the ceiling-joist; *a o* the top rafter; B *b d* the bracket to nail cornice to; *b* the gutter, and *r i* the studding, which will be required if it is desirable to finish the roof-story for sleeping-rooms.

The wall-plate is made of two thicknesses of two-inch plank nailed together, and lap jointed at the ends. The joists should be notched out to receive the longitudinal piece *h*, and the ends

of each should be sawed off square at or near the dotted line *k*. They should then be put into place, nailed to the wall-plate, and the piece *h* should be firmly nailed to each. The lower end of the side rafters are cut out at the toe to rest on the piece *h*. The upper ends are also cut to receive the piece *i*, to which they should be firmly nailed.

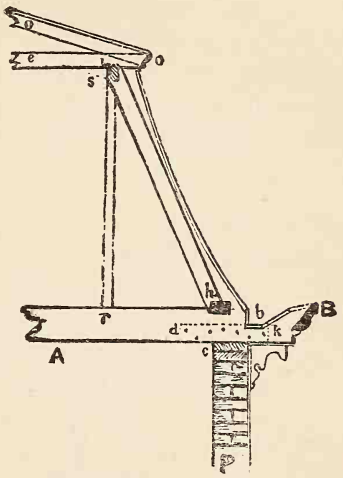


Fig. 103.

If it is required to lath and plaster on the ceiling-joists, they should be notched to rest on the piece *i*; but if the room is to remain rough, it will be as well to nail beveled pieces on each as shown by the dotted line at *s*. The end of each ceiling-joist should be sawed in shape to receive the moulding *a*, with which it is usual to finish the upper part of the roof. The top rafters may rest either on a longitudinal piece laid on the ceiling-joists, or on the piece *i*—the latter being the better method.

The curved portions of the side rafters are made separate from the straight part, and are most generally formed of two thicknesses of inch stuff, first sawed the right shape and nailed together, and then spiked to the straight part of the rafter. When so much of the roof has been put up, it will be well to mark on the ends of the floor-joists the proper depth for the gutter. This will be best done by holding a straight-edge on the ends of the joists, with incline sufficient to allow water to run off, and marking on each joist the depth it will require to be cut down. The vertical part of the gutter is cut down in a line with the lower ends of the side rafters. The cornice brackets, which are cut of a shape suitable for receiving the different parts of the cornice, are made of inch stuff, and are nailed to the floor-joists as shown by the dotted lines

and nail-marks at *d k*. The best method to pursue in putting them up is to first nail one on to the joist at either extremity of the roof, then stretch a line tight between the same points on each, and nail up the intervening brackets, with the same points touching the line. If the line is tightly stretched, and proper care is taken in nailing up the brackets, the cornice will be perfectly straight.

In Fig. 104 we have a section of a similar roof with straight sides. The different parts are lighter than those of Fig. 103, and the construction is adapted for a balloon frame building. The letters in Fig. 104 denote the same parts as the same letters in Fig. 103, and the explanation of Fig. 103 will answer for Fig. 104 so far as the same letters are concerned. P *c* is the balloon frame studding; *c*, a longitudinal piece for the floor-joists to rest upon. The studs are cut out at the top to receive the piece *c*, which must be firmly nailed to each. The floor-joists are notched to rest on the piece *c*, and will thus prevent the frame from spreading.

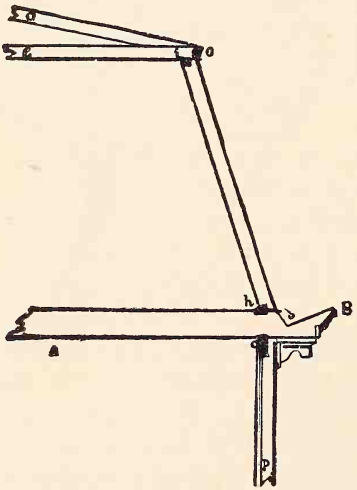


Fig. 104.

Since there is no curve on the rafter, the face of it comes flush with the inside of the gutter. Hence the side rafters are cut out at the heel to rest on the piece *h*, instead of the toe, as in Fig. 103. The piece *h* is beveled in order that the thrust on the side rafters shall not throw the lower ends out. The inside of the gutter is also made inclining so as to give as much substance as possible between the gutter and the piece *h*. The remaining parts are the same as those in Fig. 103, and the same description of those parts will answer for both cuts.

Fig. 105 shows how to find the angle-rafter and angle-cornice bracket, when the section as above described has been drawn. Let A B *c* represent the given section on the draughting-board or floor, in which the same letters denote similar parts in Figs. 103 and 104. Draw the line A *o* at an angle of 45° with A F. Then from any points C, *p*, *o*, etc., of the section as shown, draw lines perpendicular to A F, and intersecting A *o*. In order to transfer the distances A E, A *p'*, etc., on A *o* to A H, it is most convenient,

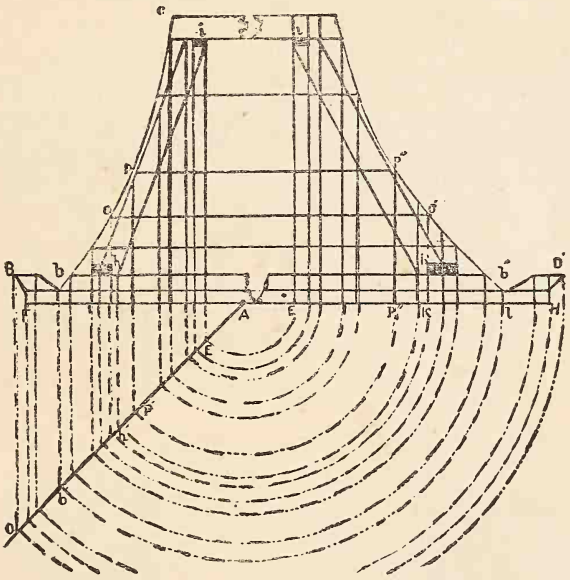


Fig. 105.

in our small illustration, to describe arcs with A as a centre; but in practice, since the distance A *o* will be several feet, it will be best to lay a straight-edge along the line A *o*, and mark the points A, E, *p'*, etc., on it; then change the position of the straight-edge, and lay it along A H—the point before on A being made to coincide with it again, and transfer the marks to the floor or board on the line A H at E', *p''*, etc. When this has been done, draw lines from

these marks and perpendicular to A H. Now draw lines from the points *c*, *p*, *o*, etc., on the section A B *c*, but parallel to F H, and intersecting the lines which are perpendicular to A H. Note the intersection of any two of these lines which were produced from the same point of the section, and this intersection will be the similar point of the angle-rafter. Perhaps the subject will be better understood if we follow the details of finding a single point of the angle-rafter; such, for instance, as that corresponding to the point *p* of the given section. From *p* draw *pp'* perpendicular to A F, and intersecting A *o* at *p'*. Make the distance A *p''* on A H equal to A *p'* on A *o*, either by describing an arc with A as a centre and A *p'* as radius, or by transferring the point *p'* to *p''* on a straight-edge, as before stated. From *p''* draw *p'' p'''* perpendicular to A H. Then from *p* on the section draw a line *p p'''* parallel to F H, until it intersects the line *p'' p'''* in the point *p.'''* This point *p'''* will be the point of the angle-rafter corresponding to the point *p* of the section. After finding all the points in a similar manner, they must be joined by the requisite curved line, and a pattern-rafter cut to fit. It will be apparent from inspection that the angle-bracket is found in the same manner.

PART IV.—COVERING OF ROOFS.

IN slating or shingling a roof, great care should be taken at the hips, ridges and valleys. Where the roof is shingled, two or three courses should be left off at the ridge until the two sides are brought up, then the courses left off should be laid on together, and in such a manner as to have them "lap" over each other alternately. This can be easily done if the workman uses a little judgment in the matter; and a roof shingled in this manner will be perfectly rain-tight, without the ridge-boards or cresting. In valleys, the tin laid in should be sufficiently wide to run up the adjacent sides far enough to prevent "back-flow" from running over it. Ample space should also be left in the gutter to permit the water to flow off freely. There is a general tendency to make these waterways too narrow, which is frequently the cause of the water backing up under the shingles, causing leakage and premature decay of roof.

There are several methods of shingling over a hip-ridge; we

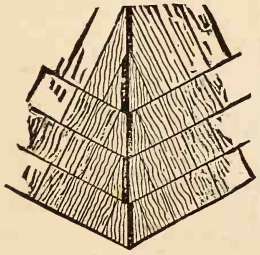


Fig. 106.

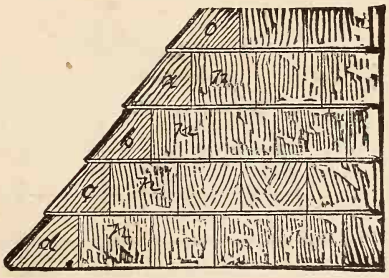


Fig. 107.

prefer, however, the old and well-tried method of shingling with the edges of the shingles so cut that the grain of the wood runs parallel with the line of hip, as shown in Fig. 106. Here it will be seen

that the shingles next to those on the hip have the grain running up and down at right angles with the eave. On Fig. 107 we show a front view of the same hip, which will give a better idea of what is meant by having the grain parallel with the line of hip. *a b c d* show the cut or hip shingles, and *n n n n* the common shingles.

The proper way to put in these shingles is to let the ends run over alternately and then dress them to the bevel of the opposite side of the roof; this is shown better at *o b d*, where the edges of the shingles are shown that are laid on the other side of the roof. The edges of *a* and *c* show on the other side of the roof, and are not seen in the drawing.

To cover a circular dome with horizontal boarding, proceed as follows:

Let A B C (Fig. 108) be a vertical section through the axis of a

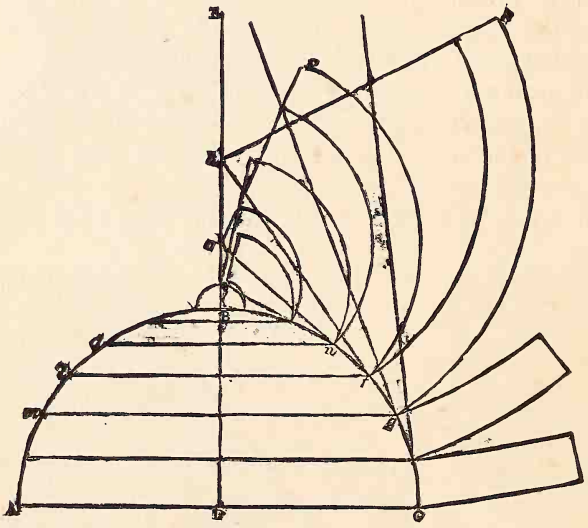


Fig. 108.

circular dome, and let it be required to cover this dome horizontally. Bisect the base in the point D, and draw D B E perpendicular to A C, cutting the circumference in B. Now divide the arc B C

into equal parts, so that each part will be rather less than the width of a board; and join the points of division by straight lines, which will form an inscribed polygon of so many sides; and through these points draw lines parallel to the base A C, meeting the opposite sides of the circumference. The trapezoids formed by the sides of the polygon and the horizontal lines, may then be regarded as the sections of so many frustrums of cones; whence results the following mode of procedure; produce, until they meet the line D E, the lines *n f*, *f g*, etc., forming the sides of the polygon. Then to describe a board which corresponds to the surface of one of the zones, as *f g*, of which the trapezoid is a section—from the point *h*, where the line *f g* produced meets D E, with the radii *h f*, *h g*, describe two arcs, and cut off the end of the board *k* on the line of a radius *h k*. The other boards are described in the same manner.

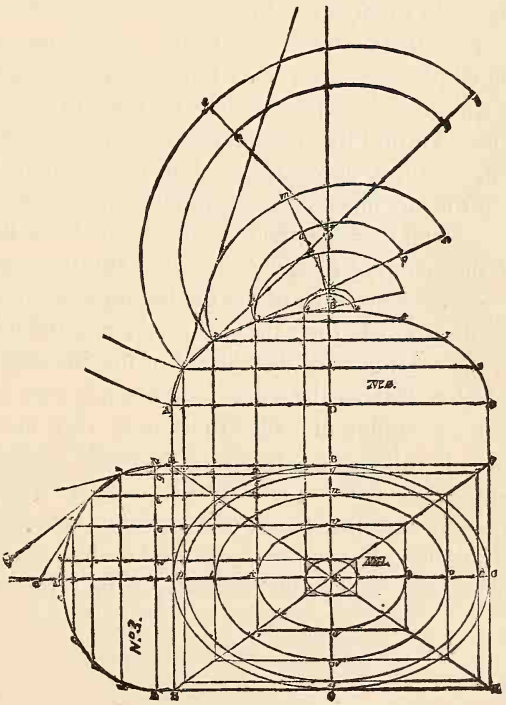


Fig. 109.

To describe the covering of an ellipsoidal dome with boards of equal width.

Let A B C D (No. 1, Fig. 109) be the plan of the dome, A B C (No. 2) the section on its major axis, and L M N (No. 3) the section

on its minor axis. Draw the circumscribing parallelogram of the ellipse F G H K (No. 1), and its diagonals F H G K. In No. 2 divide the circumference into equal parts 1 2 3 4, representing the number of covering boards, and through the points of division 1 8, 2 7, etc., draw lines parallel to A C. Through the points of division draw 1 *p*, 2 *t*, 3 *x*, etc., perpendicular to A C, cutting the diagonals of the circumscribing parallelogram of the ellipse (No. 1), and meeting its major axis in *p t x*, etc. Complete the parallelograms, and their inscribed ellipses corresponding to the lines of the covering, as in the figure. Produce the sides of the parallelograms to intersect the circumference of the section on the transverse axis of the ellipse in 1 2 3 4, and lines drawn through these, parallel to L N, will give the representation of the covering boards in that section. To find the development of the covering, produce the axis D B, in No. 2, indefinitely. Join by a straight line the divisions 1 2 in the circumference, and produce the line to meet the axis produced; and 1 2 *e k g* will be the axis major of the concentric ellipses of the covering *i f g*, 2 *h k*. Join also the corresponding divisions in the circumference of the section on the minor axis, and produce the line to meet the axis produced; and the length of this line will be the axis minor of the ellipses of the covering boards.

Before leaving the subject of roofs, it may be as well to remark that the framing of valley roofs is so very much like that of hip-roofs, that it was not necessary to make special engravings for the purposes of showing how a valley-roof is constructed or "laid out." The cuts, bevels, lengths and positions of rafters and jacks may be easily found if the same principles that govern hip-roofs are followed, as a valley rafter is simply a hip reversed.

PART V.—MITERING MOULDINGS.

ONE of the most troublesome things the carpenter meets with is the cutting of a spring moulding when the horizontal portion has to mitre with a gable or raking moulding. Undoubtedly the best way to make good work of these mouldings is to use a mitre-box. To do this make the down cuts B, B (Fig. 110) the same pitch as the plumb cut on the rake. The over cuts O, O, O, O should be obtained as follows: Suppose the roof to be a quarter pitch—though the rule works for any pitch

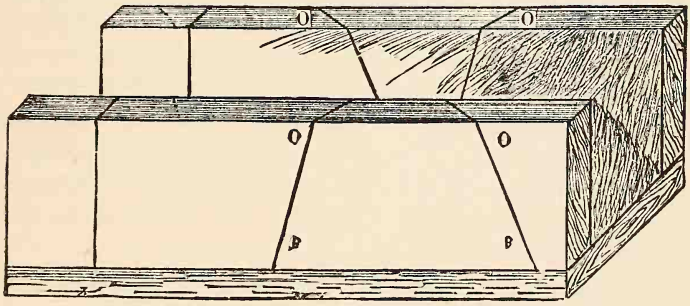


Fig. 110.

when followed as here laid down—we set up one foot of the rafter, as at Fig. 111, raising it up 6 inches, which gives it an inclination of quarter pitch; then the diagonal will be nearly 13½ inches. Now draw a right-angled triangle whose two sides forming the right angle, measure respectively 12 and 13½ inches, as shown in Fig. 112.

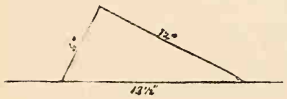


Fig. 111.

The lines A and B show the top of the mitre-box with the lines

marked on. The side marked 13½ inches is the side to mark from; this must be borne in mind, and it must be remembered that this bevel must be used for both cuts, the 12 inch side not being used at all.

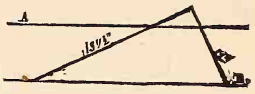


Fig. 112.

Another excellent method for obtaining the section of a raking mould that will intersect a given horizontal moulding, is given below, also the manner of finding the cuts for a mitre-box for same. The principles on which the method is based being, first, that similar points on the rake and horizontal parts of a cornice are equally distant from vertical planes represented by the walls of a building; and, second, that such similar points are equally distant from the plane of the roof. Representing the wall faces of a building by the line D B (Fig. 113), and a section of the horizontal cornice by D B *a b c d e f*—B *a b c* being the angle of the roof pitch—and following the idea given in Figure 105, draw lines *a a'*, *c c'*, *f f'*, parallel to D B and intersecting the line *k a'*, which is drawn at right angles to D B through the point B; then, with B as a centre, describe the arcs *a' k*, *c' l'*, *f' r'*, etc., intersecting the same line *k a'* on the opposite side of D B; after which extend lines from the points *r' l' k*, parallel to D B. This gives the point *k* at the same distance from D B as the points *a* and *a'*, and the line *l l'* at the same distance as *c c'*. The rest of the same group of parallel lines are found to be similarly situated with respect to A B.

From Descriptive Geometry we have the principle, that if we have given two intersecting lines contained in a plane, we know the position of that plane; hence we may represent the plane of a roof by the line B *a* and B *k* (Figs. 113 and 114); and since it will be most convenient to measure the distances required in a direction perpendicular to that plane, in following out the principle draw lines from the points *c e f*, etc., parallel to B *a* and intersecting the line B *g*, which is made perpendicular to B *a*. This gives us on B *g* the perpendicular distance of the points *c e f*, etc., from the line B *a*. From the intersections of these lines with B *g*, and with B as a centre, describe arcs intersecting the line D B at *i' h' g'*, etc.; from

these intersections with D B draw lines $l' l$, $h' p$, $g' r$, etc., parallel to B k, until they intersect the first group of lines drawn perpendicular to B k, and the intersection of each set of two lines drawn from the same point on the horizontal section will give the similar point of the rake section. Taking the point l, for example, we have, as before proved, l at the same distance from D B as c, and i being at the same distance from B a as c, B i being equal to B i', and B $i' = l' l$, $l' l$ is equal to B i'; and consequently, l is the same distance from B k as c is from B a, which is in accordance with principle already shown. The intersection of each set of lines being found and marked by a point, the contour of the moulding may be sketched in, and the rake moulding, of which the section is thus found, will intersect the given horizontal moulding, if proper care has been taken in executing the diagram.

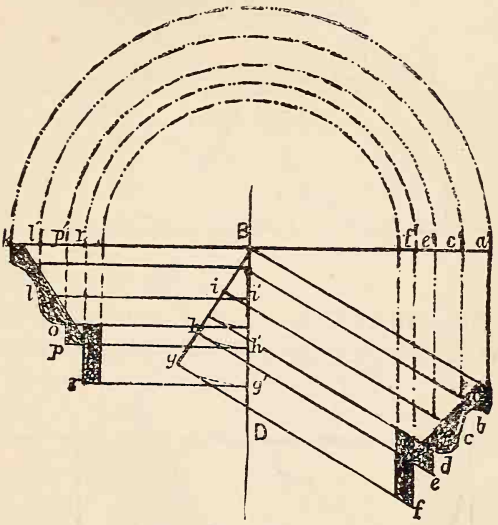


Fig. 113.

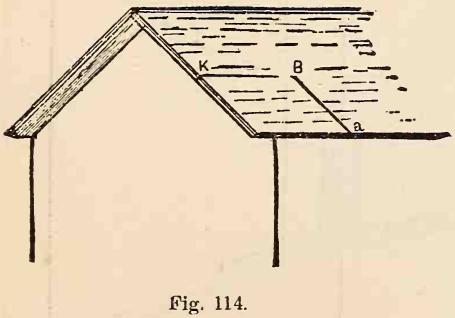


Fig. 114.

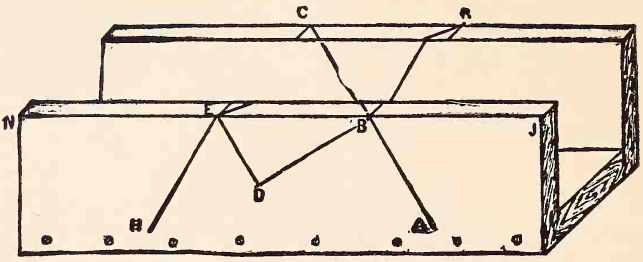


Fig. 115.

Fig. 115 shows how to find the mitre cut for the rake moulding, the cut for the horizontal one being the same as for any ordinary

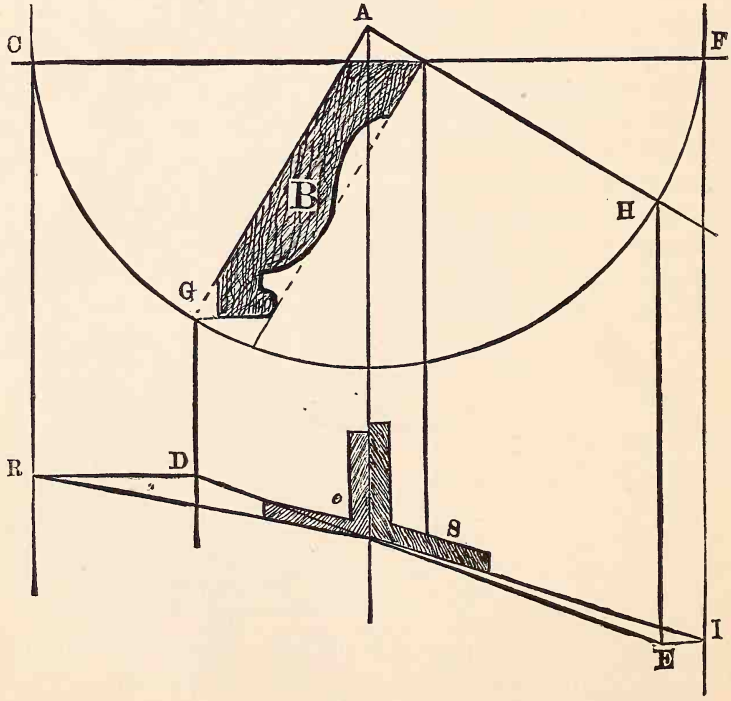


Fig. 116.

moulding. Take an ordinary plain mitre-box, N J L, and draw the line A B, making the angle A B J equal to the pitch angle of the roof. Draw B D perpendicular to A B, and make it equal to the width of the box K J; make D E parallel to A B, and extend lines from B and E square across the box to K and C; join B C and E K. A B C will be the mitre cut for two of the rake angles; H E K will be the cut for the other two angles, the angle H E N being equal to the angle A B J. In mitering, both horizontal and rake moulding, that part of the moulding which is vertical when in its place on the cornice, must be placed against the side of the box.

Lines for the cuts in a mitre box, for joining spring mouldings may be obtained as follows: If we make B Fig. 116, the moulding showing the spring or lean of the member, and D E the mitre required, then proceed as follows: With A as a centre, and the radius A G, describe the semicircle F H G C; then drop perpendiculars from the line F C, at the points F, A, H, G and C, cutting the mitre line as shown on the line I D. Draw I E parallel to F C, then from I draw I S, which will be the bevel for the side of the box, and the bevel O R will be the line across the top of the box. The mitre line, as shown here, is for an octagon, but the system is applicable to any figure from a triangle or rectangle to a polygon with any number of sides.

PART VI.—SASHES AND SKYLIGHTS.

IN the skylight, Fig. 117, of which No. 1 is the plan, and No. 2 the elevation, it is required to find the length and backing of the hip.

Let A B be the seat of the hip; erect the perpendicular A C, and

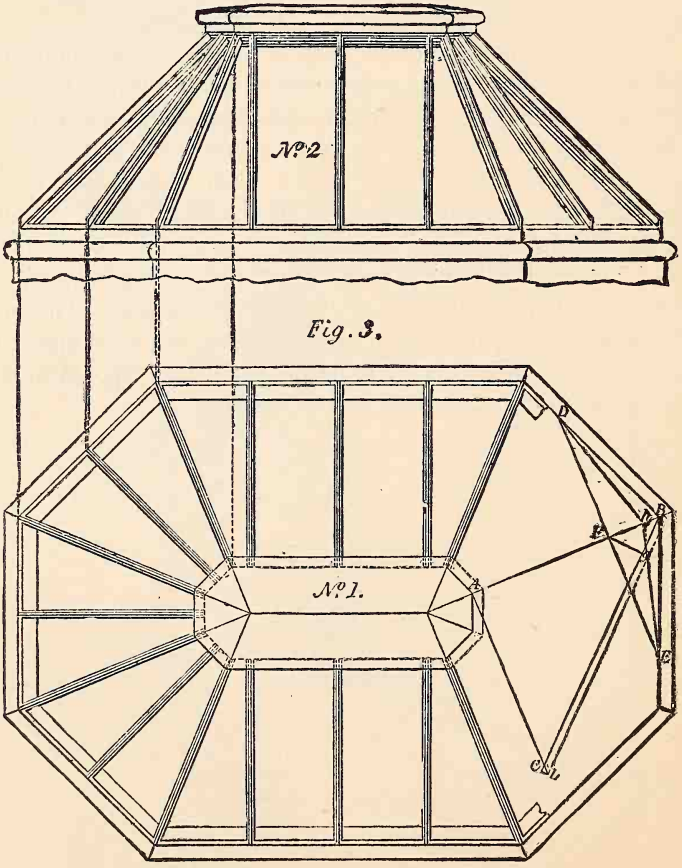


Fig. 117.

make it equal to the vertical height of the skylight, and draw B C, which is the line of the underside of the hip. The dotted line *g k* shows its upper side.

No. 2.

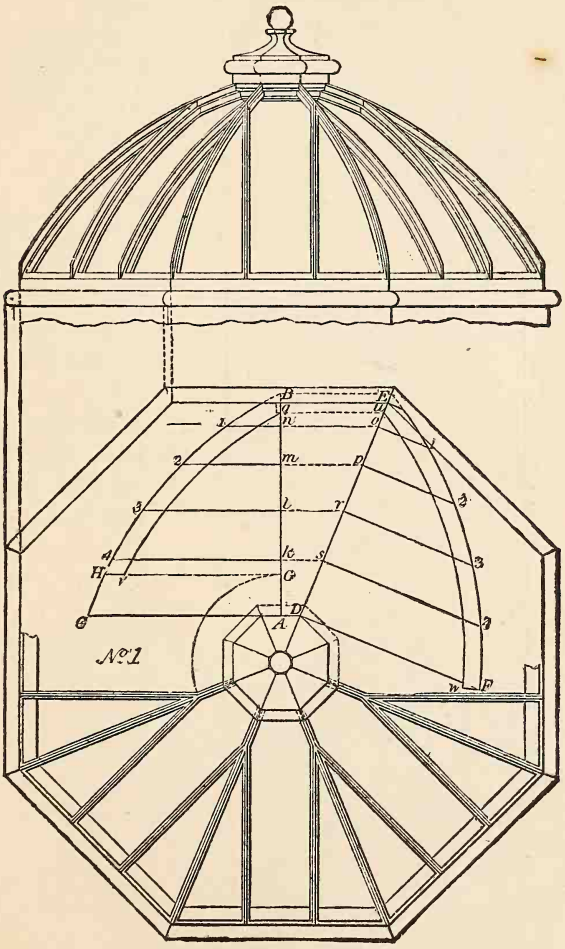


Fig. 118.

To find the backing, from any point in B C, as *g*: draw perpendicular to B C, a line *g* F meeting A B in F, and through F draw a

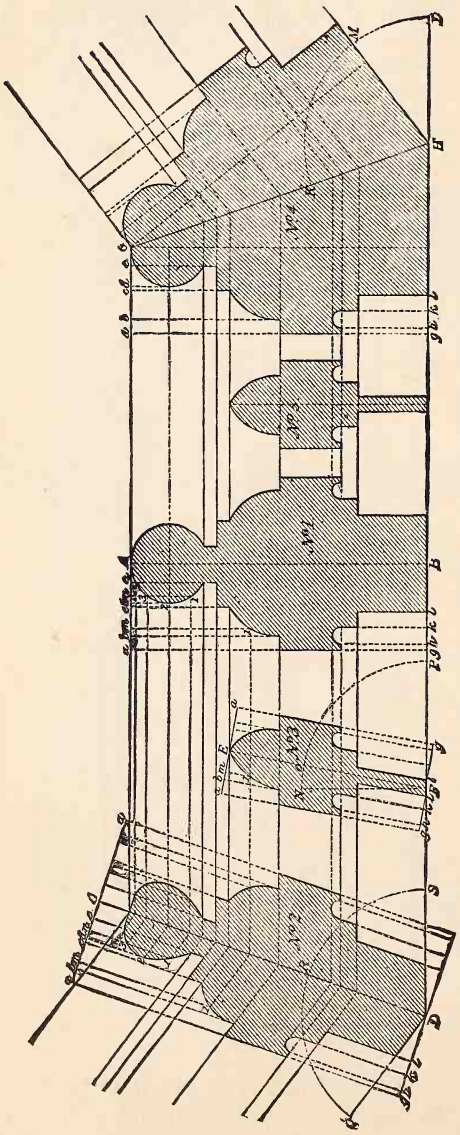


Fig 119.

line at right angles to A B, meeting the sides of the skylight in D and E. Then from F as a centre, and with F *g* as radius, cut the line A B in *h*, and join D *h*, E *h*. The angle D *h* E is the backing of the hip, and the bevel D *h* E will give the angle of backing when applied to the perpendicular side of the hip bar.

In Fig. 118, in which No. 1 is the plan, and No. 2 the elevation of a skylight with curved bars, to find the hip: let A B be the seat of the centre bar, and D E the seat of the hip. Through any divisions 1 2 3 4 C of the rib, over A B draw lines at right angles to A B and produce them to meet E D in *p o r s* D. From these points draw lines perpendicular to E D, and set up on them the corresponding heights from A B, as *n* 1 *o* 1, *m* 2 in *p* 2, etc.

Fig. 119 shows several ribs suitable for skylights. They are designedly made complicated so as to exemplify the manner of getting the shapes of the mouldings. No. 1 shows the section of a rib; these ribs may be moulded as shown, or they may be chamfered from the glass line down to the point A. No. 2 shows a hip or angle rib; the backing, Q D S, is obtained as shown in Figs. 117 and 118. No. 4 is another hip made of larger section than No. 2. Nos. 3 and 5 show sections of bars that may be used in connection with the ribs where required. No. 3 is drawn on an angle, and lettered for reference, so as to show the workman how such bars, mouldings or other work can be manipulated when the necessity for their use arises.

Figs. 120, 121 and 122 show how an angle bar for ordinary

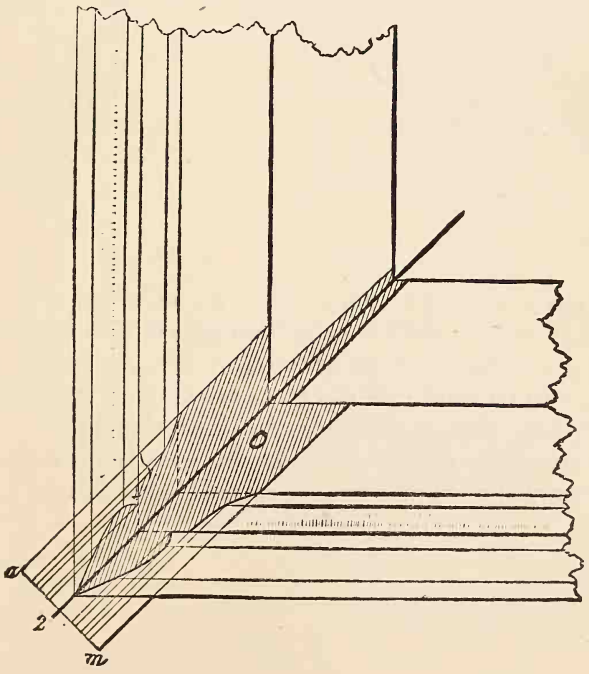


Fig. 120.

sashes may be obtained. Fig. 121 exhibits a section of the regular bar, which may be any shape. The lines *a b c d* are drawn from fixed points of the moulding. These lines are continued; they cut the lines o, o in Figs. 120 and 122. Make the distances on the lines *a b c d*, etc., in Figs. 120 and 122, the same as in Fig. 121, from the line o. The points of juncture of these lines with the lines parallel with the central sectional lines o o, will be the points through which to describe the angle bar.

Fig. 120 shows a bar set on an angle of 45°, or, as workmen term it, "it is a mitre bar." Fig. 122 is set on a more oblique angle. The rules given in the foregoing will apply to any angle.

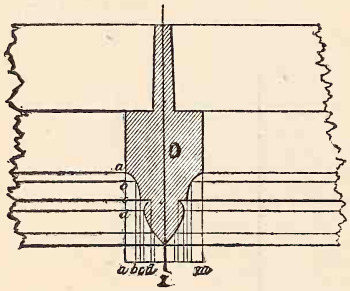


Fig. 121.

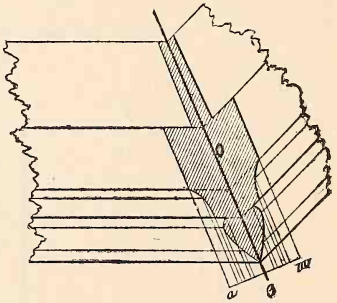


Fig. 122.

A very ready way to find the shape of an angle bar is to take a piece of the straight bar and stand it on edge in the mitre box, and saw off a thin section of the bar to the same angle as the bar required; then the outlines of this thin section will be very nearly the shape wanted. Some workmen adopt this method altogether of finding the section of their angle bars, but we do not recommend it as it is faulty in more than one respect, and is unscientific.

PART VII.—MOULDINGS.

ANGLE brackets for coves or any other mouldings may be laid off by proceeding as follows (Fig. 123): First, when it is a mitre bracket in an interior angle, the angle being 45°, divide the curve C B into any number of equal parts 1 2 3 4 5,

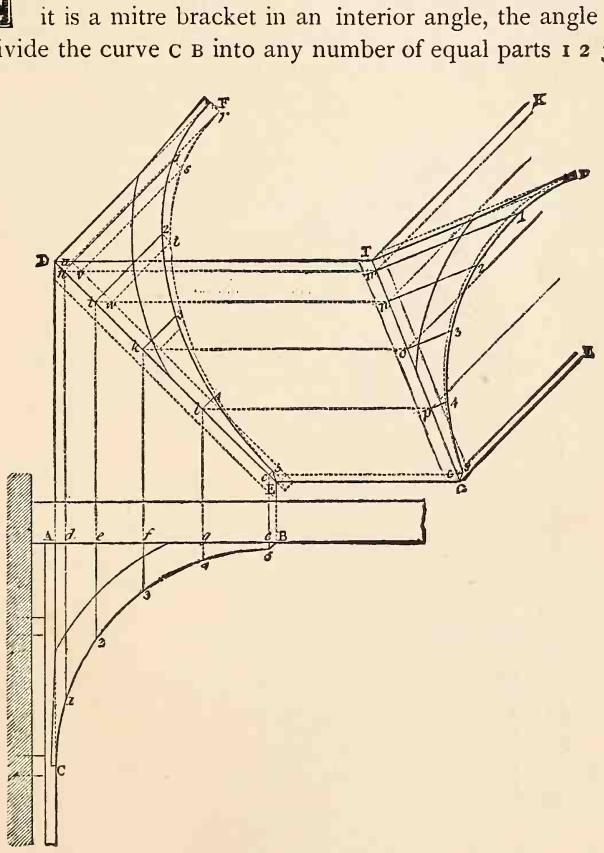


Fig. 123.

and draw through the divisions the lines 1 *d*, 2 *e*, 3 *f*, 4 *g*, 5 *c* per-

pendicular to A B, and cutting it in *d e f g c*; and produce them to meet the line D E, representing the centre of the seat of the angle bracket; and from the points of intersection, *h i k l c*, draw lines *h* 1, *i* 2, *k* 3, *l* 4, at right angles to D E, and make them equal—*h* 1 to *d* 1, *i* 2 to *e* 2, etc.; and through F 1 2 3 4 5 draw the curve of the edge of the bracket. The dotted lines on each side of D E on the plan show the thickness of the bracket, and the dotted lines *u r*, *v s*, *w t*, show the manner of finding the bevel of the face. In the same figure is shown a method for finding the bracket for an obtuse exterior angle. Let G T K be the exterior angle; bisect it by

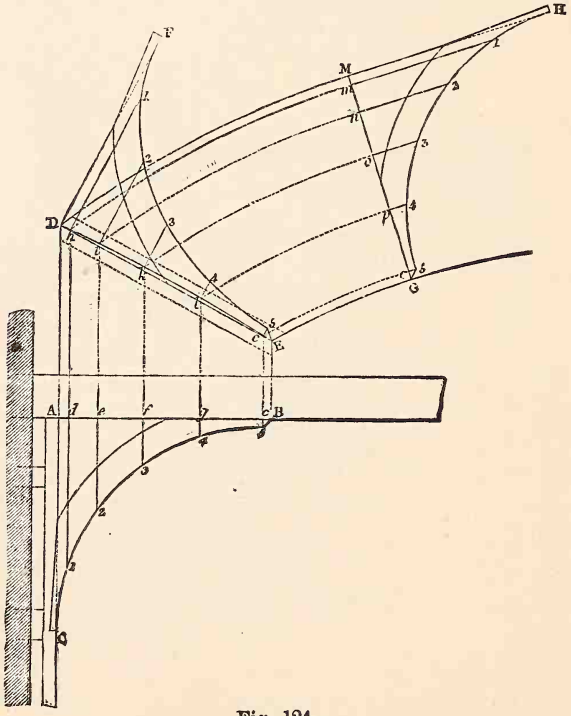


Fig. 124.

the line T G, which will represent the seat of thecentre of the bracket. The lines T H, *m* 1, *n* 2, *o* 3, *p* 4, *c* 5, are drawn perpendicular to T G,

and their lengths are found as in the former case. The bracket for an acute angle may also be found by a like process.

To find the angle bracket at the meeting of a concave curved wall with a straight wall we proceed as follows: Let A D B E (Fig. 124) be the plan of the bracketing on the straight wall, and D M, E G the plan on the circular wall; C A B the elevation on the straight wall, and G M H on the circular wall. Divide the curves C B, G H into the same number of equal parts; through the divisions of C B draw the lines C D, 1 *d h*, 2 *e i*, etc., perpendicular to A B, and through those of G H draw the parallel lines, part straight and part curved, 1 *m h*, 2 *n i*, 3 *o k*, etc. Then through the intersections *h i k l* of the straight and curved lines, draw the curve D E, which will give the line from which to measure the ordinates *h* 1, *i* 2, *k* 3, etc. Angle brackets for any corner may be found by this process if a little judgment is displayed in applying the rule.

Fig. 125 shows the manner of finding the proportions of a small moulding which is required to mitre with a larger one, or *vice versa*.

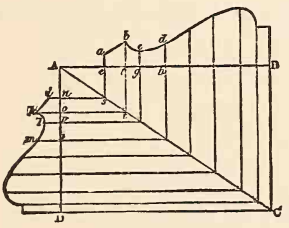


Fig. 125.

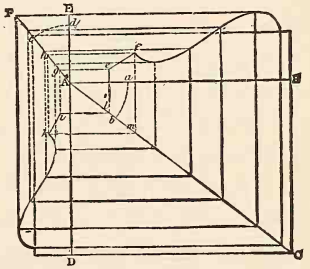


Fig. 126.

Let A B be the length of the larger moulding, and A D the length of the smaller one; construct with these dimensions the parallelogram A D C B, and draw its diagonal A C; draw parallel to B C lines *a s*, *b t*, etc., etc., meeting the diagonal in *s t*, etc., and from these points draw parallels to A B, meeting A D in *n o p r*. produce them to *i k l m*, etc., and make *n i* equal to *e a*, *o k* to *f b*, etc, and thus complete the contour of the moulding on D A, the lengths of which are diminished in the ratio of A D to A B, but its projections remain the

same as those of the larger moulding. The operation may be reversed, and the larger produced from the smaller moulding.

Fig. 126 shows the manner of enlarging or diminishing a single moulding. Let A B be a moulding which it is required to reduce to A D. Make the sides A B, D C, and A D, B C of the parallelograms respectively equal to the larger and smaller moulding, and draw the diagonal A C, produce D A to E, and make E A F equal to *a*, A, *b*, and

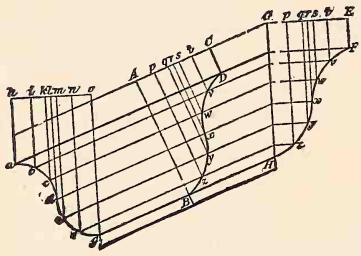


Fig. 127.

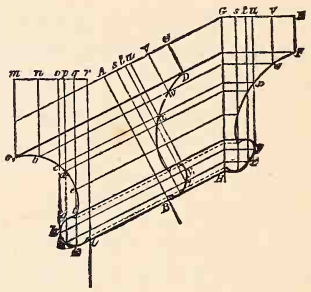


Fig. 128.

draw A F. The manner of obtaining the lengths and projections with these data is so obvious that further description is unnecessary.

To get the *contour* or outline for a raking moulding, proceed as shown in Fig. 127. The horizontal moulding is divided into any number of parts, equal or unequal, as shown at *a b c d e f g*. The line A C shows the rake or inclination. Draw lines parallel with A C, from *a* to D, *b* to *v*, etc. Drop a line A B, perpendicular to A C, at any convenient point on the rake, make the distance A C equal to *h o*; then drop the lines *p q r s t*, and where these lines cut the lines *a b c d e f g*, these points of contact will be in the curve line of the raking moulding, as at D *v w x y z*. From these points trace the curve, which will be the proper shape for the moulding. The divisions and lines shown at G H E F gives the proper shape for the moulding at the top return. It requires no further explanation.

Fig. 128 shows another application of the foregoing rule. This will apply to raking string-boards, cornices, architraves, or cabinet mouldings. The method of working it out is so obvious as to require no further explanations.

A method is here shown of mitering a gothic capital or base round a square standard. A, Fig. 129, shows the standard. S S S S

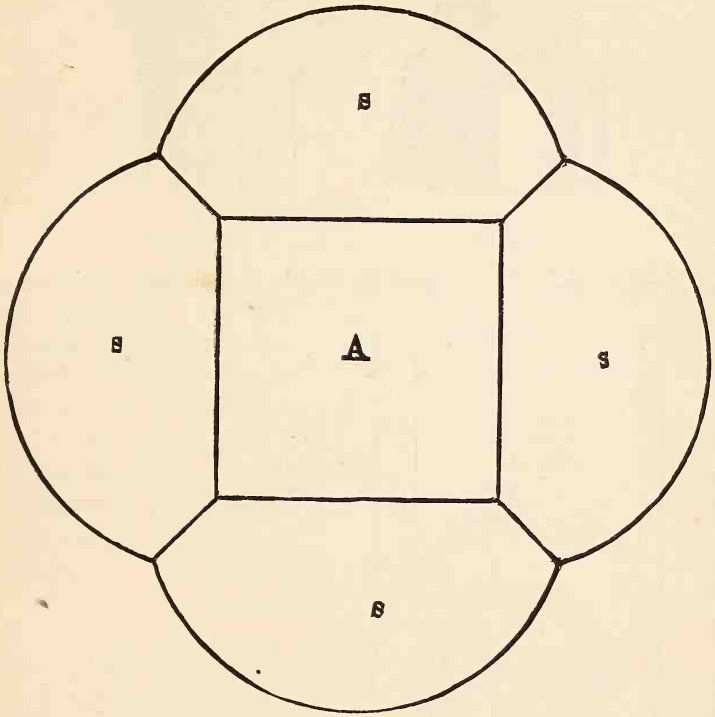


Fig. 129.

show the blocks that form the capital or base. The two other figures, 130 and 131, show the base and capital completed.

Sometimes there are more than four pieces in the cluster, but the same principles rule when such is the case; the central standard, however, should have as many sides on it as there are pieces in the cluster.

Sometimes the workman will find it necessary to mitre in circles between two lines of mouldings, and to do so the circular mouldings must be made with a diameter large enough to have the solid

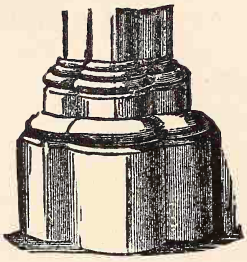


Fig. 130.

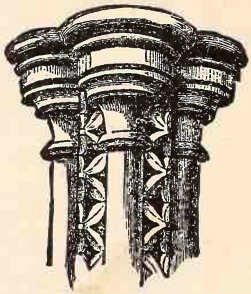


Fig. 131.

wood adjoin the solid wood of the running mouldings, as shown at Fig. 132. It will be seen that the points of juncture of the various members of the mouldings do not run in a straight line, thus making the mitre-joint a little curved, which admits of the mouldings working together accurately without requiring to be pared.

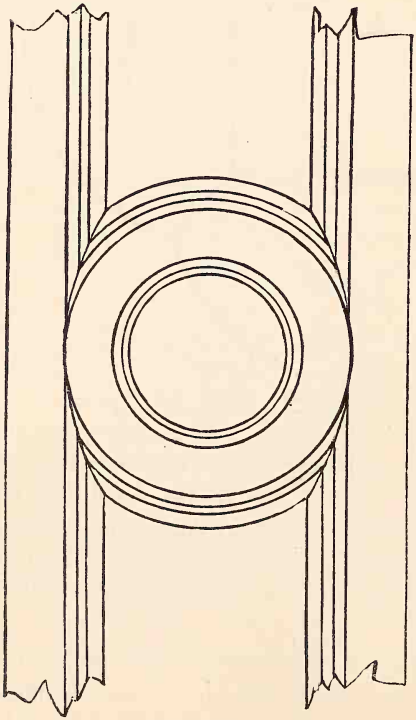


Fig. 132.

Figs. 133, 134, 135 and 136 show how various joints are made by the junction of circular mouldings with straight mouldings, and mouldings with more or less curvature.

A "spring" moulding is one that is made of thin stuff, and is leaned over to make the proper projection, as shown at Fig. 138. A shows the spring moulding; B the space left vacant by

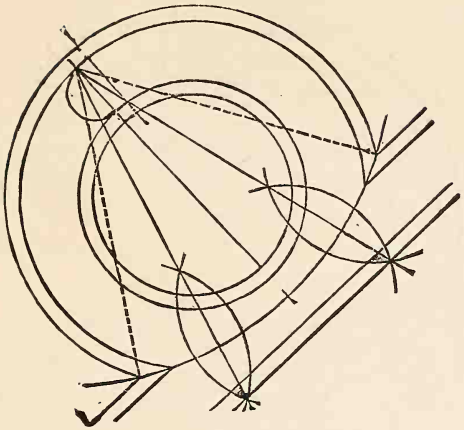


Fig. 133.

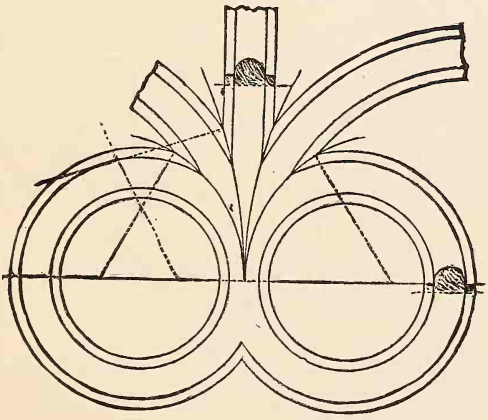


Fig. 134.

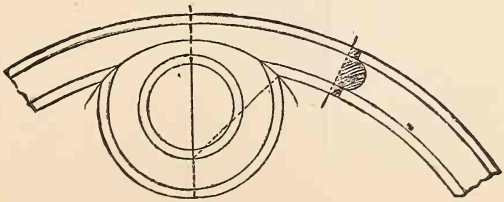


Fig. 135.

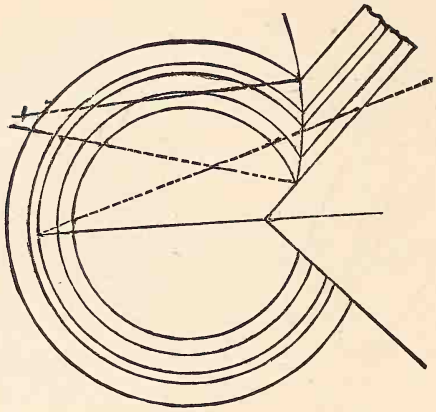


Fig. 136.

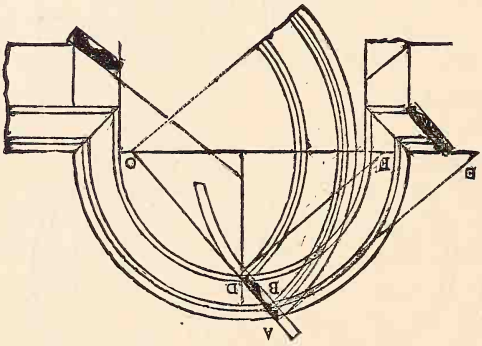


Fig. 137.

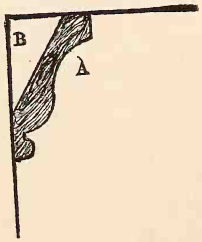


Fig. 138.

the leaning of the moulding. These mouldings are difficult to mitre, more particularly so when the joint is made with a raking moulding that "springs" also. Some of the methods given for obtaining the cuts for raking mouldings may be used for cutting these mouldings when the work is straight; bu when circular, the application of other methods is sometimes necessary. Many times the workman will come across very knotty operations of this kind to work out, and the following diagrams will then prove exceedingly useful: Fig. 137 exhibits an elevation of a circular moulding mitered into a horizontal moulding. The shape and plane of the moulding is shown at B. It is evident that by producing the line A D to intersect the centre line of the arc at C, the central point will be obtained, from which the circular piece required for the moulding may be described. E A and F D give the radius for the curves of both edges when the stuff is in position, as shown in the elevation.

Fig. 139 shows the application of the same rules to a circular elevation of a different form standing over a straight plan. The back lines of the moulding are produced until they bisect a horizontal line drawn through the centre, from which the circular cornice was struck, as shown by the lines A B and C D. In other respects the operation is precisely the same as at Fig. 137.

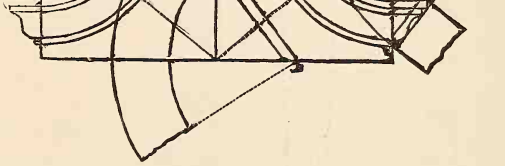


Fig. 139.

PART VIII.—JOINERY.

TO make a good dovetail joint properly requires considerable skill and care on the part of the operator; but when completed, no other system of joining boards at right angles proves so satisfactory. This joint has three varieties: 1st, the common dovetail, where the dovetails are seen on each side of the angle alternately; 2d, the lapped dovetail, in which the dovetails are seen only on one side of the angle; and, 3d, the lapped and mitred dovetail, in which the joint appears externally as a common mitre-joint. The lapped and mitred joint is useful in salient angles,

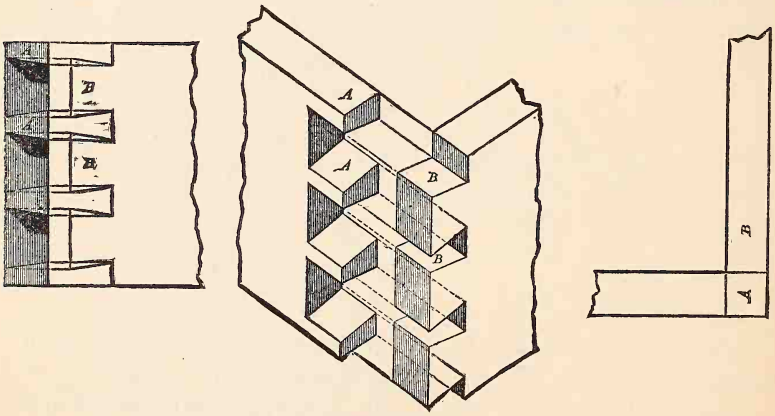


Fig. 140.

in finished work, but it is not so strong as the common dovetail, and therefore, in all re-entrant angles, the latter should be used. The three varieties are shown in the annexed engravings.

Fig. 140, No. 1, shows the open dovetail, and No. 2 is a perspective view of the same showing how the work appears when ready to put together. No. 3 shows the work com-

plete. Fig. 141, Nos. 1 and 2, show the lapped dovetail. This style is generally used for drawers and work where it is desirable that end wood should not be seen in the front side. No. 3 shows the angle and position of lines of juncture when put together. Fig. 142, No. 1, 2, 3 and 4, show the method of making a combined dovetail and mitre joint. This style of joint is sometimes called a "blind" dovetail-joint; it is chiefly used in making

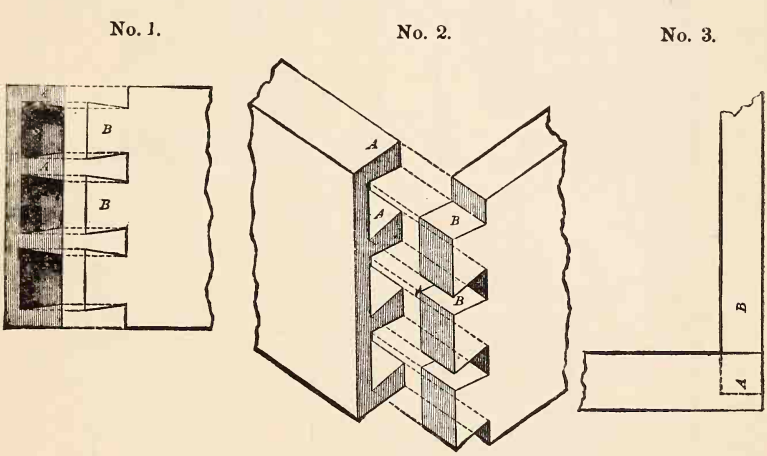


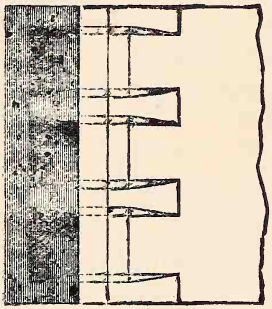
Fig. 141.

fancy boxes where all the corners are exposed. The joint shows a mitre on the outside, the pins and mortises of the dovetails being hidden from view.

Figs. 143 and 144, show two methods of dovetailing hoppers, trays and other splayed work. The reference letters A and B show that when the work is together A will stand directly over B. Care must be taken when preparing the ends of stuff for dovetailing, for hoppers, trays, etc., that the right bevels and angles are obtained, according to the rules explained for finding the cuts and bevels for hoppers and works of a similar kind, in the examples given further on.

Figs. 145, 146 and 147, show how to get the "cuts" or bevels for hoppers. It is old, but correct and simple. Let Fig. 145 represent

No. 1



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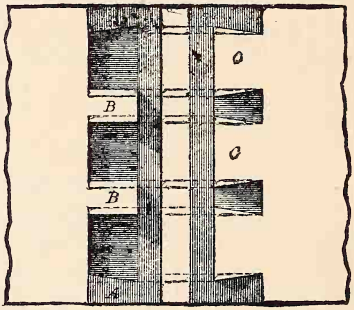

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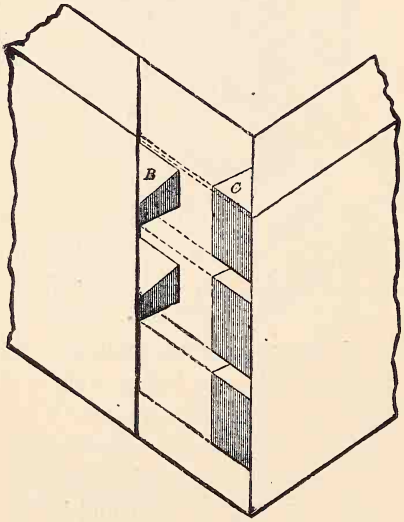

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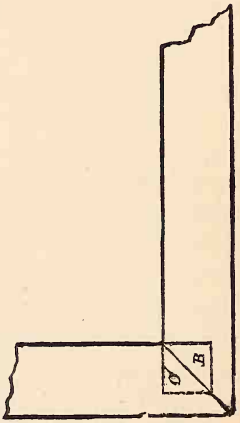


Fig 142.

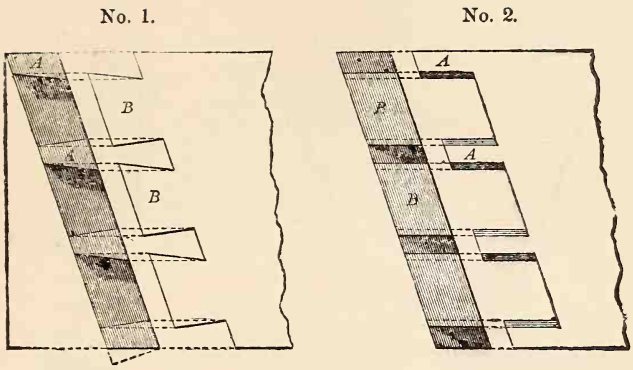


Fig. 143.

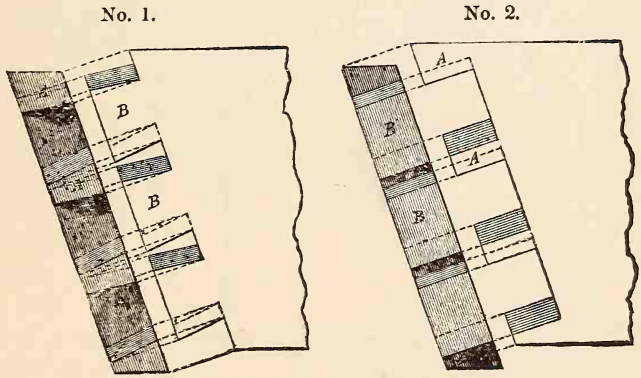


Fig. 144.

a box whose sides splay, or we may call it a hopper or bread-tray; or it may form the back and two ends of a carriage seat, if we take off one side and cut it off at the dotted lines, where a seat would be required. The lines N R show the bevel or splay of the box. Take this bevel and transfer it to the end of one piece of the stuff you intend using, as shown at P, Fig. 146. Then take the distance S O, on the marking gauge, and run a line on the board from O to K, Fig. 147. Now make the line A B the same bevel as the hopper, or, the bevel as now set, may be applied with the stock resting

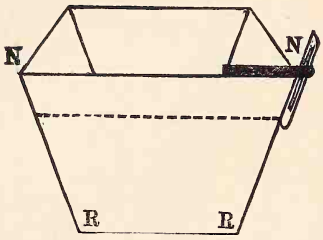


Fig. 145.

Fig. 146.

on the edge R, then the blade will represent the line A B. Square up from M, cutting A R at P, then square over on the edge the line P E. Then connect A E, which will be the angle required for a butt joint, the inside corner being the longest. If it is required to mitre the joint, set off the thickness of the stuff as measured at Z O, from A to X, then the line X E will be the bevel sought.

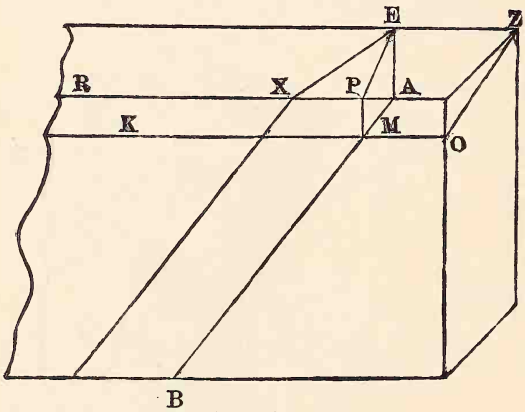


Fig. 147.

Another method for accomplishing the same result is given below. This method in many shapes and forms, has been used from time immemorial by workmen, more particularly by carriage makers to obtain the bevels of splayed seats; the present way of expressing it, however, is comparatively recent.

* If we make A 1, Fig. 148, represent the elevation of our hop-

* From "The Steel Square and Its Uses."

per, and B 1 a portion of the plan, we proceed as follows: Lay off S, which is the bevel of one side, and S P O the section of one end.

Place one foot of the dividers where the bevel is shown, and with S as radius describe the arc S U, intersecting the right line U in the point U. At S erect the perpendicular S T, and draw the line U T at right angles to C U. Connect T with centre; then the triangle S T is the end bevel required. The line T is the hypothenuse of a right-angled triangle, of which U may be taken for the perpendicular

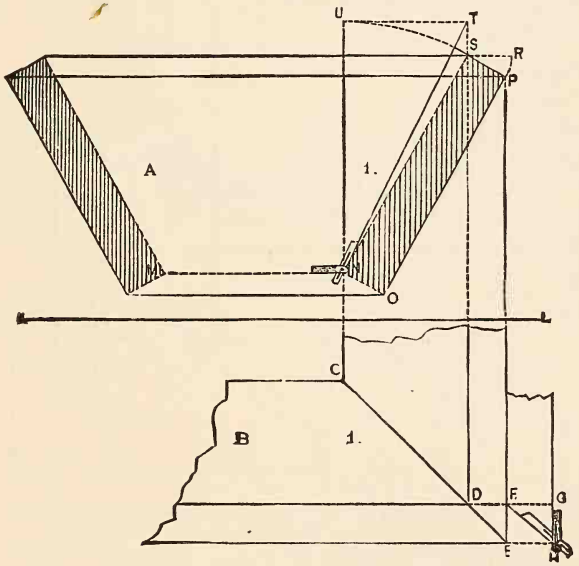


Fig. 148.

and U T for the base. To find the mitre of which D E is the plan, project S and P, as indicated in the plan by the full lines. With S P as radius and S as centre, describe the arc P R. In the plan draw D G, on which lay off the distance S R, measuring from F, as shown by F G. Then G H F is the mitre sought.

Fig. 149 shows the rule for finding the bevels for the sides of the hopper. From M, the point at which E M intersects B C, or the inner face of the hopper, erect the perpendicular M L, intersecting

R F, or the upper edge of the hopper, in the point L. Then L C shows how much longer the inside edge is required to be than the outside. In the plan draw T V parallel to S U X, making the distance between the two lines equal to C F of the elevation, or, equal to the thickness of one side. From the point L in the elevation drop the line L W, producing it until it cuts the mitre line N O, as shown at

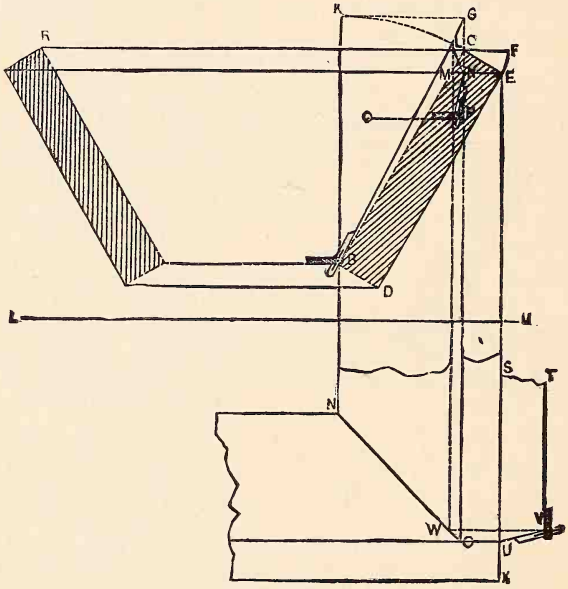


Fig. 149.

W. From W, at right angles to L W, erect the perpendicular W V, meeting the line T V in the point V. Connect V and U; then T V U will be the angle sought. This bevel may be found at once by laying off the thickness of the side from the line E M, as shown by N P in the elevation, and applying the bevel as shown. This course does away with the plan entirely, provided both sides have the same inclination.

There are several other ways by which the same results may be obtained; some of these will no doubt occur to the reader when laying out the lines as shown here.

PART IX.—MISCELLANEOUS PROBLEMS.

BENT WORK: Fig. 150 exhibits a method of obtaining the correct shape of a veneer for covering the splayed head of a gothic jamb. E shows the horizontal sill, *e f* the splay, *f* A the line of the inside of jamb, *o* the difference between front and back edges of jamb, B A the line of splay. At the point of junction of the lines B A, *f* A, set one point of the compasses, and with the radius A B draw the outside curve of *n*; then with the radius A S draw the inside curve, and *n* will be the veneer required. This will give the required shape for either side of the head.

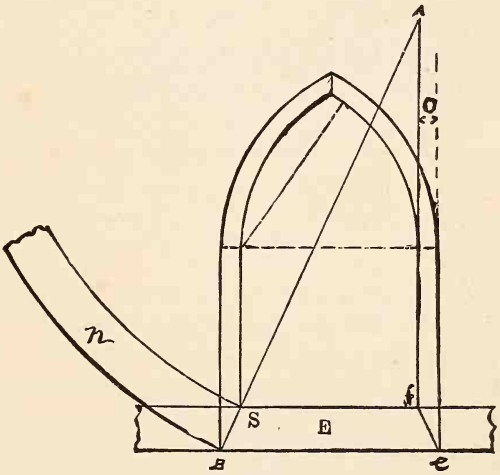


Fig. 150.

Developing Cylinders.—Cylinders may be considered as prisms, of which the base is composed of an infinite number of sides. Thus we shall obtain graphically the development of a right cylinder by a rectangle of the same height, and of a length equal to the circumference of the circle, which serves as its base, measured by a greater or lesser number of equal parts.

But if the cylinder (Fig. 151) be oblique, and it is required to draw its profile as inclined, describe on the centre of the axis of the inclined profile, and perpendicular to it, the circle or ellipse which

forms the base; and divide its circumference into a number of equal parts, and through these divisions draw lines parallel to the axis *a b*, *c d*, *e f*, *g h*, etc.

Then to find the projection of the base on a horizontal plane, from the points *a c e g*, where the lines from the divisions of the circumference meet the line of the base *a k*, let fall perpendiculars on a line *a′ k′*, parallel to the base, and produce them indefinitely beyond it. From the points *m′ n′ o′ p′*, where these perpendiculars intersect the line *a′ k′*, set off on each side *m′* 1, *m′* 15, and *n′* 2, *n′* 14, equal to the ordinates of the circle distinguished by the same letters and figures, and so on with the other divisions; and through the points thus obtained, draw the ellipse *a*, 4, *k*, 12, which is the projection of the base of the cylinder on a horizontal plane.

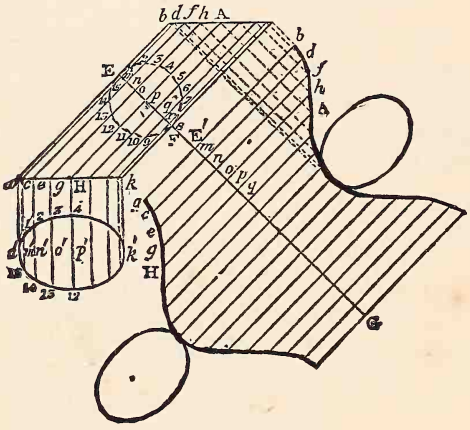


Fig. 151.

To obtain the development of the cylindrical surface, produce E F indefinitely to G, and set out on it from E′ the divisions of the circumference of the circle 1 2 3 4, etc., in the points *m n o p*, etc.; through these, draw lines parallel to the axis, and transfer to them the lengths of the corresponding divisions of the profile, as E *a*, E *b*, *m c*, *m d*, *n e*, *n f*, etc.; then draw the curves *a c e g* H, *b d f h* A, through the points thus obtained. The addition of the elliptic surfaces, which form the base and head of the solid, and which are similar and equal to *a′*, 4, *k′* 12, completes the development.

The extent E′ G will not be truly the same as that of the periphery of the circle E F, inasmuch as the distances in the latter are but

the cords of segments; if, however, the number of divisions employed be ample, the amount of the error will, for practical purposes, be inappreciable.

Taking Dimensions.—In taking the dimensions of any triangular figure, make a sketch of it as in Fig. 152, No. 1, and on each line

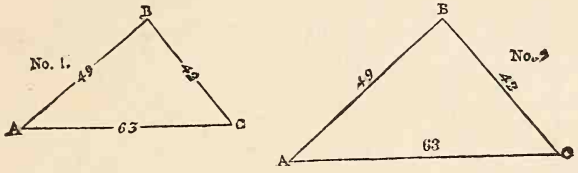


Fig. 152.

of the sketch mark the dimensions of the side of the figure it represents. Then, in describing the figure, either to its full dimensions, or to any proportionate scale, draw any straight line as A B, No. 2 and make it equal to the dimension marked on the corresponding line A B of the sketch No. 1. From the centre A and with the radius A C, describe an arc at C; then from the centre B, with the radius B C, describe an arc intersecting the former: join A C, B C, and the triangle A C B is the figure required.

The dimensions of any figure are taken on the principle above

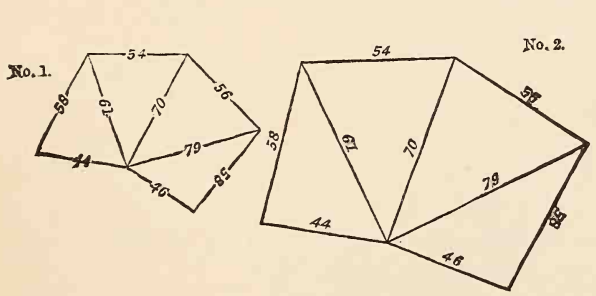


Fig. 153.

illustrated. If the figure is not triangular, it is divided into triangles, in the manner shown by Fig. 153, Nos. 1 and 2.

In Fig. 154, Nos. 1 and 2, the manner of taking dimensions, when one or more sides of the figure are bounded by curved lines,

is illustrated. When, as at A B (No. 1), the side is a circular arc, its centre is obtained as follows: The extreme points A B, and the point of junction C of the intermediate line E C with A C and B C, give three points in the curve. From A and B, therefore, with any

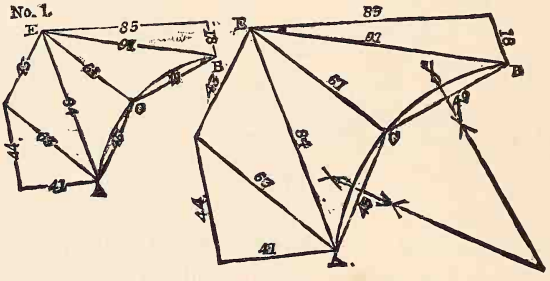


Fig. 154.

radius, describe arcs above and below the curve; from C, with the same radius, intersect these arcs; through the intersections draw straight lines meeting in D; and D is the centre of the curve, and D A, D B, or D C its radius.

PART X.—TIMBER WORK.

JOINTS AND STRAPS.—PLATE I. shows a number of joints in framing that will frequently be found useful by the workman. Fig. 1, No. 1, shows the joint formed by the meeting of a principal rafter and tie-beam, *c* being the tenon. The cheeks of the mortise are cut down to the line *d f*, so that an abutment, *e d*, is formed of the whole width of the cheeks, in addition to that of the tenon; and the notch so formed is called a joggle. No. 2 shows the parts detached and in perspective, and it will be seen that a much larger bearing surface is thus obtained.

Fig. 2.—No. 1 is a geometrical elevation of a joint, differing from, the last by having the anterior part of the rafter truncated, and the shoulder of the tenon returned in front. It is represented in perspective in No. 2.

Fig. 3.—Nos. 1 and 2 show the geometrical elevation and perspective representation of an oblique joint, in which a double abutment or joggle is obtained. In all these joints, the abutment, as *d e*, Fig. 1, should be perpendicular to the line *d f*; and in execution, the joint should be a little free at *f*, in order that it may not be thrown out at *d* by the settling of the framing. The double abutment is a questionable advantage; it increases the difficulty of execution, and, of course, the evils resulting from bad fitting. It is properly allowable only where the angle of meeting of the timbers is very acute, and the bearing surfaces are consequently very long.

Fig. 4.—Nos. 1 and 2 show a means of obtaining resistance to sliding by inserting the piece *c* in notches formed in the rafter and the tie-beam: *d e* shows the mode of securing the joint by a bolt.

Fig. 5.—Nos. 1 and 2 show a very good form of joint, in which the place of the mortise is supplied by a groove *c* in the rafter, and the place of the tenon by a tongue *d* in the tie-beam. As the parts can be all seen, they can be more accurately fitted, which is an ad

vantage in heavy work. In No. 1 the mode of securing the joint by a strap *a b* and bolts is shown.

Fig. 6.—Nos. 1 and 2 is another mortise-joint, secured by a strap *a b* and cotter or wedge *a*.

Fig. 7 shows the several joints which occur in framing the king-post into the tie-beam, and the struts into the king-post. A is the tie-beam; B, the king-post; and C and D, struts. The joint at the bottom of the king-post has merely a short tenon *e* let into a mortise in the tie-beam. The abutment of the strut D is made square to the back of the strut, as far as the width of the king-post admits, and a short tenon *f* is inserted into a mortise in the king-post. The abutment of the joint of C is formed as nearly square to the strut as possible.

The term *king-post*, as has been already stated, gives quite an erroneous notion of its functions, which are those of a suspension tie. Hence the necessity for the long strap *b a* bolted at *d d*, and secured by wedges at *c*, in the manner more distinctly shown by the section, Fig. 8, No. 2. The old name *king-piece* is better than king-post.

Fig. 8.—No. 1 shows the equally inappropriately named *queen-post*. A is the tie-beam; B, the post tenoned at *e*; C, the strut; and D, the straining-piece. The strap *b a*, and bolts *d d*.

Fig. 9.—In this figure, the superior construction is shown, in which a king-bolt of iron C D is substituted for the king-post. On the tie-beam A, is bolted by the bolts *a e*, *d f*, the cast-iron plate and sockets *a b c d*, the inner parts of which, *h g*, *h g*, form solid abutments to the ends of the struts B B. The king-bolt passes through a hole in the middle of the cast-iron socket-plate, and is secured below by the nut D. A bottom-plate *e f* prevents the crushing of the fibres by the bolts.

PLATE II.—Figs. 1 to 5 show various methods of framing the head of the rafters and king-posts by the aid of straps and bolts. Fig. 6 shows the heads of the rafters halved and bolted at their junction, and a plate laid over the apex to sustain the bolts which are substituted for the king-post. One bolt necessarily has a link formed in it for the other to pass through.

Fig. 7 shows at D what may be considered the upper part of the same king-bolt as is shown in Plate I., Fig. 9, with the mode of connecting the rafters. A cast-iron socket-piece C receives the tenons *a a* of the rafters A A, and has a hold through it for the bolt, the head of which, *b*, is countersunk. B is the ridge-piece set in a shallow groove in the iron socket-piece. An elevation of the side is given, in which G is the bolt, F the socket-piece, and E the ridge-piece.

Figs. 8, 9, 10 and 11 illustrate the mode of framing together the principal rafter, queen-post, and straining-piece. In the first three examples the joints are secured by straps and bolts; and in the last example the queen-bolt D passes through a cast-iron socket-piece C, which receives the ends of the straining-piece and rafter, as those of the two rafters are received in Fig. 7.

Figs. 12 and 13 show modes of securing the junction of the collar-beam and rafter by straps; and Figs. 14 and 15, modes of securing the junction of the strut and the rafter by straps.

Lengthening Beams, etc.—In large works in carpentry it is often necessary to join timbers in the direction of their length, in order to get them long enough to answer the purpose. When it is necessary to maintain the same depth and width in the lengthened beam, the mode of joining called *scarfing* is employed. Scarfing is performed in a variety of ways, dependent upon whether the lengthened beam is to be subjected to a longitudinal or transverse strain. This method of joining is illustrated in Plate III., Figs. 1 to 13.—The methods are self evident.

PART XI.—SWING JOINTS.

HINGING.—PLATE IV. shows a number of methods of hinging. Fig. 1, No. 1, shows the hinging of a door to open to a right angle, as in No. 2.

Fig. 2, Nos. 1 and 2, and Fig. 3, Nos. 1 and 2. These figures show other modes of hinging doors to open to 90°.

Fig. 4, Nos. 1 and 2. These figures show a manner of hinging a door to open to 90°, and in which the hinge is concealed. The segments are described from the centre of the hinge *g*, and the dark shaded portion requires to be cut out to permit it to pass the leaf of the hinge *g f*.

Fig. 5, Nos. 1 and 2, show an example of centre-pin hinge permitting the door to open either way, and to fold back against the wall in either direction. Draw *a b* at right angles to the door, and just clearing the line of the wall, or rather representing the plane in which the inner face of the door will lie when folded back against the wall; bisect it in *f*, and draw *f d* the perpendicular to *a b*, which make equal to *a f* or *f b*, and *d* is the place of the centre of the hinge.

Fig. 6, Nos. 1 and 2, another variety of centre-pin hinging opening to 90°. The distance of *b* from *a c* is equal to half of *a c*. In this, as in the former case, there is a space between the door and the wall when the former is folded back. In the succeeding figures this is obviated.

Fig. 7, No. 1. Bisect the angle at *a* by the line *a b*; draw *d e* and make *e g* equal to once and a half times *a d*; draw *f g* at right angle to *e d*, and bisect the angle *f g e* by the line *c g*, meeting *a b* in *b*, which is the centre of the hinge.

No. 2 shows the door folded back when the point *e* falls on the continuation of the line *f g*.

Fig. 8, Nos. 1 and 2. To find the centre draw *a b*, making an angle of 45° with the inner edge of the door, and draw *c b* parallel

to the jamb, meeting it in *b*, which is the centre of the hinge. The door revolves to the extent of the quadrant *d c*.

PLATE V.—Fig. 1, Nos. 1 and 2; Fig. 2, Nos. 1 and 2; and Fig. 3, Nos. 1 and 2, examples of centre-pin joints, and Fig. 4, Nos. 1 and 2, do not require detailed description.

Fig. 5, Nos. 1, 2, and 3, show the flap with a bead *a* closing into a corresponding hollow, so that the joint cannot be seen through.

Fig. 6, Nos. 1, 2, and 3, show the hinge *a b* equally let into the styles, and its knuckle forming a part of the bead on the edge of the style B. The beads on each side are equal and opposite to each other, and the joint pin is in the centre.

Fig. 7, Nos. 1, 2, and 3. In this example, the knuckle of the hinge forms portion of the bead on the style B, which is equal and opposite to the bead on the style A.

In Fig. 8, Nos. 1, 2, and 3, the beads are not opposite.

PLATE VI.—Fig. 1, shows the hinging of a back flap when the centre of the hinge is in the middle of the joint.

Fig. 2, Nos. 1 and 2, shows the manner of hinging a back flap when it is necessary to throw the flap back from the joint.

Fig. 3, Nos. 1 and 2, is an example of a rule-joint, such as is required for the shutter *s*. The further the hinge is imbedded in the wood, the greater will be the cover of the joint when opened to a right angle.

Fig. 4, Nos. 1 and 2, shows the manner of finding the rebate when the hinge is placed on the contrary side.

Let *f* be the centre of the hinge, *a b* the line of joint on the same side, *h c* the line of joint on the opposite side, and *b c* the total depth of the rebate. Bisect *b c* in *e* and join *e f*; on *e f* describe a semicircle cutting *a b* in *g*, and through *g* and *e* draw *g h* cutting *d c* in *h*, and join *d h*, *h g*, and *g a* to form the joint.

Fig. 5, Nos. 1 and 2, is a method of hinging employed when the flap on being opened has to be at a distance from the style. It is used in doors of pews to throw the opened flap or door clear of the mouldings of the coping.

Fig. 6, Nos. 1 and 2, is the ordinary mode of hinging the shutter to the sash frame.

PART XII.—USEFUL RULES, TABLES, DATA AND MEMORANDA.

CENTRES.—A few remarks on the subject of centres may prove of use to the carpenter and joiner, as he frequently has to prepare and fix them in place. I have given a few general directions in preceding pages, but not sufficient to satisfy every requirement; therefore, a few observations here will not be untimely.

Centres are temporary structures of wood, with curved upper surfaces upon which arches are built, and left until they are consolidated and have taken their bearing, after which the centres are removed.

For large arches, such as those of bridges, very elaborate centres are required, with special arrangements for easing and striking them gradually; but in ordinary buildings the centres are very simple; the arches for which they are required being generally of small span and common construction.

Centres for very small and narrow arches may consist simply of a piece of wood cut to the curve of the soffit of the arch, and supported under it by uprights.

For longer arches, such as those of tunnels, sewers, etc., the centre is composed of a number of curved pieces or ribs, and have narrow battens or lagging nailed across them.

For stone arches or very rough brick arches, the battens may be placed from one to two inches apart, but for superior brick arches they should be placed close together, and the arrises or corners taken off with a rough jack plane. As few nails as possible should be used in putting on the lagging, in order to save trouble when the centering is done with and being removed.

When the arches are small, single pieces may form the centre;

and when the opening does not exceed six or eight feet, the centre may be built up of several layers of thin boards, with the joints broken, and the whole well nailed together. More elaborate centres, for bridges, large openings in warehouses, factories or tunnels, should be built of timber, properly framed together in such a manner that they may be taken down and apart without cutting the timber of which they are composed.

In constructing all but the very smallest arches arrangements should be made for *easing* the centres, so as to gradually deprive the arches of their supports. This is done by means of pairs of greased wedges introduced between the heads of the supports and the resting points of the centres.

After the arch has been turned, and the haunches filled in, the points of the wedges may be lightly struck with a hammer so as to drive them outwards from the rib under which they are placed, thus lowering the centre a very little; which causes the whole of the arch to settle slightly and uniformly, and to take its bearing, the mortar being compressed in the joints. The arch is then left until the mortar has set, after which the centres are removed altogether. Some builders defer the easing of the centres for a day or two after the arch is finished. When an arch is built of soft stone or bricks, and the super-incumbent weight is great, it is better not to ease the centering for some time, as the pressure on the edges of the voussoirs is apt to crack and chip them. In centres for very important stone arches, wedges or screws are frequently placed under each piece of lagging, so that the work may be eased "course by course," and the supports wedged up again if the settlement is too rapid. Arrangements are sometimes adopted for easing all the wedges at the same time, so that the whole arch may settle uniformly, but this is complicated and expensive, and on these accounts will never become popular.

Seasoned materials should always be employed for centres intended for the better sort of arches.

Estimates.—It frequently happens that the carpenter is called upon to make estimates of buildings, more particularly of buildings of the cheaper sort, and in order to do this intelligently and with

any degree of accuracy, he should be able to figure up the dimensions of all the materials used in and about the building, and to, also, know the cost of the various materials delivered on the site, the exact price of the various kinds of labor, and have a thorough knowledge of the details of his own trade, and a fair knowledge of the practical operations of the other trades that will be employed on the building estimated for. This knowledge is necessary in order to provide for unseen contingencies which frequently arise in building, and which are often sources of annoyances to both builders and owners. A few hints are here given which may aid the estimator, and for further information on this subject I refer him to the *Builder's Guide and Estimator's Price Book*, as it contains rules, prices of labor and material, costs of manufactured stuff, such as sashes, doors, stairs, hardware, glass, paints, plumber's goods, etc.

The following is a form for an estimate; it may be ruled on foolscap paper, and when the blank columns are properly filled out, and the estimate completed, it should be filed away for future reference, and if any errors or mistakes have been made, corrections should be made on the margin with memoranda attached, noting how the mistakes occurred. The form is only intended as a guide, and therefore only includes a few of the items required about a building. It must, of course, be changed to suit the requirements of the building under consideration:

FORM FOR AN ESTIMATE.

Quantities.	Description of Work.	Price.	$	c.
250 yards cube.	Excavating for foundation walls, drains, posts, etc., etc., and removing stuff.....			
36 Cords	Rubble masonry in foundation walls, including all material set in mortar, pointed and complete, including removing rubbish.....			
80 Thousand	brick laid in mortar, in walls and partitions, joints struck including setting of all walls, plates, boards and other timber.....			
2500 Feet,	lineal, of flooring joists, 11 x 3, fixed complete with all trimming pieces, etc.....			
15 Squares of	$1\frac{1}{2}$ inch matched flooring laid complete, including nails, etc.....			

FORM FOR AN ESTIMATE (*Continued*).

Quantities.	Description of Work.	Price.	$	c.
16	Doors, 7 x 2·10, 2 inches thick, in four panels, moulded on both sides, with 7 inch moulded architraves, casing and saddle, including a lock worth 75 cents, and 3 inch butt hinges; hung and fixed complete...			
10	Sashes and frames, sashes 6 ft. by 3.6 in six lights, glazed (state kind of glass), best delf knobs, wrought iron bolts, hinges, and fixed complete.....			
10	Sets of inside shutters panelled, to open in two pieces with flaps, panelled and moulded soffit, including sills, etc., all fixed complete.....			
10	Double windows, describe.....			
10	sets of summer blinds and frames, each side to open in two, with moveable slats, fixed all complete.....			
950	Yards superficial of plastering in two coats and set with fine stuff, including lathing and all materials..			
	Cornices.....			
	Centre-pieces.....			

The foregoing is lengthy enough to give the intelligent workman a clear idea of the proper method of making an estimate.

To make the matter clearer, however, the following general memoranda of items are given, so as to show how the work should be described or itemized in order to avoid omissions and mistakes:

GENERAL MEMORANDA OF ITEMS FOR ESTIMATES.*

Excavation, per cubic yard, ascertain the quantity of earth to be excavated for foundation walls, drains, fence posts, etc.

Foundation Walls, per cubic foot, 128 feet to the cord of masonry. Find the number of cubic feet in walls and footing courses, deducting all openings over 9 feet in width.

Tile Drains.—Calculate the number of lengths, bends and junctions required, add cost of laying and connecting, including covering in, etc.

Galvanized Iron and Lead Pipes.—State the length and diameters of all galvanized iron pipes necessary, and the weight of lead pipes per yard lineal, together with all traps, overflow pipes, and cocks necessary.

* Builder's Guide and Estimator's Price Book, p. 9.

Water Closets.—If water closets are to be provided state how to to be fitted up.

Bath.—State description of bath, if of galvanized iron or other metal, including fixing in frame and casing.

Brick Walls per foot cube. 20 bricks (of 8 ins. x 2½) are generally allowed to a cubic foot. Find the number of cubic feet in the walls, division walls and chimneys, deduct all openings. Measure all chimneys as solid.

Carpentry. Under this head commence with the heavy timbers, such as flooring joists, roofing wall plates, lintels, bond timber, wood-bricks, insertions for cornices, projections for galleries, studding for partitions, furring for ceilings, skirting, groining, etc. Framing for stables, fencing and posts.

If the building is a frame or a balloon, find the number of studs, sills, rafters and other timbers used, also the number of feet of rough boarding, siding, shingling, nails, and other items necessary to complete a wooden structure.

Joiners' Work.—This will include all floors, doors, windows, blinds, shutters, casings, skirting, and fittings of every description in wood work, all the different sized doors, windows must be kept separate.

Stove Pipe Rings.—State number.

Mantel Pieces and Grates.—Number mantel pieces and grates, and state price, provide for hearth stones and fixings all complete.

Closets.—State quantity of shelving required, cloak nails, hooks, etc. Calculate for plasterings and skirtings.

Pantry.—Describe the fitting up of pantry, whether with cupboards or open shelves, and state if with sinks.

Kitchen.—State how to be fitted up with shelves, pantry, closets, etc.

Bell Hanging.—State number of bells, fixed complete.

Gas Pipes.—State number of lights in each room, etc.

Staircases.—Describe the different stairs and their length, width and thickness; state the kind of balusters and their number, also newels, give the dimensions of hand rail.

Roof.—Describe the kind of roof, whether metal, and what kind.

If slate, number of plies of felt under it, gravel—do. If shingles, state what kind, etc.

Gutters and Conductors.—State the width of gutters and how to be lined, and also length and direction of gutters.

Outside Porches.—Provide for all double doors, and construction of porches as described in specifications as well as all steps leading thereto.

Fences.—State the different kinds of fences and take a price at per lineal ft., including gates and everything necessary to complete them.

Of course there will be many other items than these described in a specification, but sufficient has been stated to enable the builder to calculate as to the value of the building he contemplates erecting, before giving in a tender for the work.

It is understood that a plan and specification will be provided for the use of the estimator. It is not necessary that the plan, and elevation when given, should be in ink, or very elaborate. A pencil drawing will often be all that will be required.

After the quantities are taken out and written down in the form herein given, and the prices current for material and labor in each particular added, the prices being for the completed work, as, for instance, the price of a door should mean the cost of a door, frame, casings, achitraves, lock, hinges, mouldings, fixing and hanging complete, including the painting. By adopting this system the estimator will know that each item is complete, and it will be almost impossible to err in the final result. When all the items are written up, and everything is known to be entered, the totals should be made up, and 20 per cent. added to cover contingencies.

It is a convenient practice to those unaccustomed to taking out quantities, to note down on the plan of each room the quantity of plastering, cornice, flooring, wainscoting, windows, doors, blinds, etc., contained therein, and abstract afterwards the different items under their proper headings.

Sufficient has now been said on this subject to enable the workman to estimate with a tolerable degree of accuracy.

Nails.—The following shows how many nails are required for doing certain kinds of work:

To nail on 1000 shingles from 3½ to 5 lbs. of fourpenny nails or 3 to 4 lbs. of threepenny nails.

1000 lath requires about 6½ lbs. of threepenny nails.

1000 feet of clapboards requires 18 lbs. of sixpenny box nails.

1000	"	boarding	20	"	eightpenny nails.
1000	"	"	25	"	tenpenny "
1000	"	top floors, sq. edge	38	"	" "
1000	"	" "	41	"	twelvepenny "
1000	"	matched flooring	31	"	tenpenny "
1000	"	" "	42	"	twelvepenny "
1000	"	studding	1	"	tenpenny "
1000	"	furring, 1 x 3	45	"	" "
1000	"	" 1 x 2	65	"	" "
1000	"	fine finish	30	"	eightpenny finish nails.

The following shows how many nails to the pound there are in the different sizes:

Name.	Length.	Number to a pound.
3d. fine,	1 inch,	557
3d.	1¼ "	385
4d.	1⅜ "	254
5d.	1½ to 1¾ inch.	232 to 180
6d. finish,	2 "	215
6d.	2 "	154
7d.	2½ "	141
8d. finish,	2½ "	150
8d.	2½ "	90
9d.	2¾ "	76
10d. finish,	3 "	84
10d.	3 "	62
12d.	3¼ "	50
20d.	3⅝ "	36
30d.	4 "	24
40d.	4½ "	18
50d.	5⅛ "	13
60d.	6 "	9
70d.	7 "	6

The numbers given are about right, but sometimes there may be more or less per pound than as above, as some manufacturers make their nails lighter in weight than others. In estimating for work, however, the above will be found pretty nearly right.

Cornices.—In the course of my experience I have frequently been asked as to what were the proper proportions for a cornice? This question is somewhat difficult to answer, on account of the great number of conditions required to be known before a correct one can be given. Of course, if the drawings for a building are prepared by an experienced architect—which they ought to be where possible—there will be no trouble in deciding on the proper dimensions for projections and widths of the various members. For country carpenters, however, who have to depend on their own knowledge of proportion for deciding on the various sizes and dimensions constituting a cornice, I give the following hints, though it must be understood that the sizes here given may be varied somewhat to suit different locations and different tastes.

For dwellings that are nicely finished, it is usual to allow one and a half inches projection of soffit for every foot in height, measuring from sill to plate.

If the buildings are more than two and a half stories in height, this projection would be too much, and where the buildings are only one story in height, the proportion would be too little.

For verandas, window and door cornices, piazzas, porches and bay-windows, one and a half inches projection to each foot in height will be about right.

The width of the frieze will depend somewhat on its position; in a frame house, two stories, it may be anywheres from twelve to sixteen inches wide, according to the number of embellishments or mouldings it contains. The plainer it is the narrower it may be. The taller the building the wider the frieze will require to be, and buildings less than two stories in height should not have friezes more than from ten to twelve inches in width.

Crown mouldings or facias should never be more than half the width of the frieze, and in a majority of cases should be less. When they are moulded and have several members planted or "stuck" on

them, they may be wider than when plain. In the Queen Anne style of building, where the frieze and facia are loaded with small mouldings, beads and rosette ornaments, a greater width of surface is admissible.

In designing verandas, porches, bay-windows and similar work, a great deal of latitude may be allowed, and the width of the frieze may be varied from six to ten inches, or in the case of arched openings the frieze may be made from eight to eighteen inches in width, to suit the surrounding conditions. Of course, wide friezes or facias on verandas must be relieved with mouldings, or be broken into panels at regular intervals or at symmetrical distances; or the frieze may have brackets, singly or in pairs or triplets, placed at regular or symmetrical irregular distances, in such a manner as to relieve the monotony of the wide field of frieze exposed. The crown or upper portion of the cornice above the projection, which is also called the facia, must not increase in width on verandas, piazzas, porches and bay-windows, in the same proportion as the frieze, and the designer must be very careful when preparing drawings or sketches for this work, and avoid long flat and unbroken surfaces on facias. On no part of the exterior of a building is good, honest work more necessary than on the cornices over bay-windows, porches and verandas; every mitre and joint should be true and perfect, and every running and other ornament should be straight, regular and smooth.

Base-boards or Plinth.—The height of the base-boards of a room is governed somewhat by the height of the room itself, and to a certain extent also by the length of the straight walls. One and an eighth inches to every foot in height of the room gives a very fair proportion, but in most cases one and a quarter inches suits much better; in rooms of great length, however, where the walls are straight and unbroken, an extra inch or more might be added to the whole width, which will have a tendency to give it a more pleasing effect than if left narrower. In many cases the width or height of a base will be determined by circumstances or by the taste of designer. The wider the base the more mouldings it should have upon it, but the mouldings should never project past the face of the base.

A base-board may be square or plain, ornamented by a bead or moulding *stuck* upon it, or by a detached moulding; or it may be sunk to form a double plinth, with or without mouldings on each offset.

Sometimes the base-board is let into a groove in the floor, which prevents the crack or opening that always takes place between the floor and the lower edge of the base when the latter shrinks.

This practice is not so common in America as in England, but as an excellent substitute we adopt the following method: Procure a piece of stuff—hard wood is the best for the purpose—about three-quarters of an inch wider than the base is thick, and about one inch thick. A groove is then made in the piece about a half an inch deep, and half an inch wide, and three-quarters of an inch from the face of the stuff showing in the room. A moulding may be stuck on the face-edge, or it may be rounded off from the edge of the groove to the floor. This strip is carefully nailed down on the floor in proper place and straight, nicely mitered at the corners in both re-entrant and external angles, and left level and straight on the top. The base-board is then made with a lip on its lower edge, gauged from its face and made just the size to fill the groove made in the running piece. This lip is forced into the groove, and the base-board is then nailed on to the grounds, studding or other means of fastening. This makes very good work, for should the joists in the floor shrink and let the floor down, or the base shrink, the lip would draw out of the groove a little, but no joint would be visible, and no wind or vapors could get into the room from this source.

If no provision of this kind is made to meet the shrinkage, then the base-board must be "scribed" to the floor, so that it will fit closely at every part.

It is best to dove-tail the corners at the internal angles, and mitre the external angles. All butt-joints should have a tongue or *feather* in them. This keeps them even on the face and makes the joint so much stronger. In all cases of corners, the mouldings must show a mitred angle, either by being cut so or by being scribed.

Double bases consist of two base-boards, joined together in the direction of their width. The members may be of equal width or

the lower part may be narrower or wider, according as the design or conditions demand it. Wherever the joint takes place there ought to be a moulding, bead or offset *stuck* on the stuff, so as to cover the line of junction, which, in case of shrinkage, hides the joint.

Dado, Wainscot, or Surbase.—For the sake of ornament, and to prevent the wall from being injured by chairs knocking up against it, a moulded bar, called a "chair-rail," is sometimes fixed at a height of about three feet from the floor and parallel with the base. The rail should be fastened well to the wall-furring or grounds provided for that purpose. These rails should never be less than three inches wide. The interval between the rail and base is called the "dado," and the whole work, base, dado, and rail combined, is often called by workmen the wainscot or wainscoting, and the top rail alone is termed the surbase. Sometimes, in halls, hotels, churches and public buildings, the wainscoting is made as high as six feet or more from the floor, and is broken into panels of various forms or made up of narrow strips matched and beaded or left with a V joint. Sometimes a tier of ornamental tiles is run around at an appropriate distance from the surbase, with a second rail and moulding running under the tile line.

Woods.—In these days every carpenter and joiner should be able to manipulate all our native hard woods, as the day is at hand when nearly all the better sort of houses, public buildings, churches, schools, club-rooms, stores, banks and offices will be finished in hard wood; therefore, it is quite necessary that workmen should become acquainted with the methods of working and finishing them, and my advice is that each workman that desires to push himself forward in his trade, should acquire a knowledge of the various kinds of hard woods, their qualities and adaptabilities for various purposes. The country workman scarcely ever works any other woods than pine and hemlock, and sometimes, perhaps, spruce and a little walnut. He has no idea of the fine effect produced by a combination of ash and walnut; or black birch, or cherry and maple, or of oak and walnut, when properly handled; or our country houses would contain more rooms finished off with native hard

woods than we now have. A parlor or dining-room finished with some of our common native hard woods costs but very little more than the same room would finished with pine and daubed over with paint or some other abomination. It is astonishing what a fine effect white ash has when used as finish in a country house, when properly wrought and prepared. The best filling for woods of this kind is the now celebrated "Wheeler's Wood-filler," which may be found done up in cans, in almost any paint-store in the country, directions for using accompanying each can. Heretofore, one of the great objections urged against the use of hard wood for finish by country workmen was the difficulty of finishing the work after it had been put in place. To oil or varnish the wood before filling was simply to spoil the whole work and make it look worse than if painted, which, indeed, it had to be in a great many cases, to hide its ugliness. A filler, however, properly applied, fills up the pores of the wood and hardens its surface, and excludes the dust and dirt from penetrating into the wood and disfiguring it, and varnish applied on this shows an even surface that is at once rich and pleasing.

The following tables refer more particularly to timbers intended for constructive than for decorative purposes, and will be found more useful to the carpenter than to the joiner, but in many cases will be found useful to both.

Mr. Hodgkinson found that timber when wet had not half the strength of the same timber when dry. This is an important point to consider in subaqueous structures.

Resistance to Crushing Across the fibres.—When a vertical piece of timber stands upon a horizontal piece, the latter is compressed at right angles to the length of the fibres, and in this position it will not withstand so great a compressive force per square inch as does the vertical piece, whose fibres are compressed in the direction of their length.

Not many experiments have been made on this point.

Tredgold found that Memel pine was distinctly indented with a pressure of 1000 lbs. per square inch, and English oak with 1400 lbs. per square inch.

TABLE SHOWING THE WEIGHT, STRENGTH, ETC., OF VARIOUS WOODS.

Wood seasoned.	Weight of a cubic foot (dry).	Tenacity per Sq. inch. lengthways of the grain.		Modulus of Rupture.	Modulus of Elasticity.	Resistance to Crushing in direction of fibres.[1]		Comparative Stiffness and Strength, according to Tredgold. Oak being 100.[2]	
	Lbs.	Tons.		Lbs.	Lbs.	Tons per sq. inch.		Stiffness.	Strength.
		From	*To*			Moderately dry.	Thoroughly dry.		
Acacia	48	5·0	8·1	..	1,152,000 to 1,687,500			98	95
Alder	50	4·5	6·3	..	1,086,750			63	80
Ash, English	43 to 53	1·8	7·6	12,000 to 14,000	1,525,500 to 2,290,000	3·8	4·2	89	119
" American	30	2·45		10,050	1,380,000		2·5	77	79
Beech	43 to 53	2·1	6·6	9,000 to 12,000	1,350,000	3·4	4·2	77	103
Birch	45 to 49	6·7		11,700	1,645,000	1·5	2·8		
Cedar	35 to 47	1·3	5·1	7,400 to 8,000	486,000	2·5	2·6	28	62
Chestnut	35 to 41	4·5	5 8	10,660	1,140,000	..		67	89
Elm, English	31 to 37	2·4	6·3	6,000 to 9,700	700,000 to 1,340,000	2 6	4·6	78	82
" American	47	4·1		14,490	2,470,000		4·1	139	114
Fir, Spruce	29 to 32	1·3	4·5	9,900 to 12,300	1,400,000 to 1,800,000	2·9	3·0	72	86
" Dantzic	36	1·4	4·5	13,806	2,300,000		3·1	130	108
" American red pine	34	1·2	6·0	7,100 to 10,290	1,460,000 to 2,350,000		2·1	132	81
" American yellow pine	32	0·9		8,454	1,600,000 to 2,480,000		1·8	139	66
" Memel	34	4·2	4·9	..	1,536,000 to 1,937,750		6	114	80
" Kaurie	31	2·0		11,334	2,880,000		2·6	162	89
" Pitch pine	41 to 58	2·1	4·4	14,088	1,252,000 to 3,000,000		3·0	73	82
" Riga	34 to 47	1.8	5-5	9,450	870,000 to 3,000,000		2·1	62	83
Greenheart	58 to 72	3·9	4·1	16,500 to 27,500	1,700,000	5·8	6·8	98	165
Jarrah	63	1·3		10,800	1,187,000		3·2	67	85
Larch	32 to 38	1·9	5·3	5,000 to 10,000	1,360,000		2·6	79	103
Mahogany, Spanish	53	1·7	7·3	7,600	1,255,000 to 3,000,000		3·2	73	67
" Honduras	35	1·3	8·4	11,500 to 12,600	1,596,000 to 1,970,000		2·7	93	96
Mora	57 to 68	4·1		21,000 to 22,000	1,860,000	..		105	164
Oak, English	49 to 58	3·4	8 8	10,000 to 13,600	1,700,000 to 1,750,000	2·9	4·5	100	100
" American	61	3·0	4·6	12,600	2,100,000		3·1	114	86
Plane	40	5·4		..	1,343,250	..		78	92
Poplar	23 to 26	2·68		..	763,000	1·4	2·3	44	50
Sycamore	36 to 43	4·3	5 8	9,600	1,040,000		3·1	82	111
Teak	41 to 52	1·47	6·7	12,000 to 19,000	2,167,000 to 2,414,000	2·3	5·4	126	109
Willow	24 to 35	6·25		6,600	..	1 3	2·7		
Hornbeam	47·5	9.1		..	..		3·7	..	108

[1] From Hodgkinson's experiments on short pillars 1 inch diameter, 2 inches high, flat ends, and Laslett's on 2-inch cubes.

[2] This ratio is not always confirmed by the values of the moduli of elasticity as found by more recent experiments, and given in the fifth column of the above table.

Mr. Hatfield's experiments chiefly on American woods, are quoted in Hurst's *Tredgold*, and form the basis of a table in Hurst's *Pocket-Book*, from which the following are taken :—

	Force per sq. inch required to crush the fibres transversely 1·20 inch deep.
Fir, spruce,	·22 tons.
Pine, Northern or Yellow,	·60 "
" White (*P. strobus*) American,	·27 "
Mahogany, Honduras,	·58 "
" St. Domingo,	1·92 "
Oak, English,	·90 "
" American,	·84 "
Ash, American,	1·03 "
Chestnut,	·42 "

Resistance to Shearing.—On this point also but few experiments have been made.

The resistance to shearing in direction of the fibres of the wood is of course much less than that across the fibres.

Wood.	Resistance to Shearing per sq. inch in lbs.	
	Along Fibres.	Across Fibres.
Fir	556 to 634[1]	
Oak	2300[2]	4000[2]
American oak	780[3]	
Ash and elm	1400[2]	
Spruce	600[2]	
Red pine	500 to 800[2]	

[1] Barlow *On Strength of Materials*, p. 23. [2] Rankine's *Civil Engineering*.
[3] Hatfield, quoted in Hurst's *Tredgold*.

If the reader wishes to pursue this subject further he will find it fully discussed in *Hatfield's Transverse Strains*, price $6.00; *Hurst's Tredgold*, price $6.00; *The Builder's Guide and Estimator's Price-Book*, price $2.00; and in *Gwilt's Encyclopedia of Architecture*, price $18.00.

The following items are submitted, as they place before the reader, in a handy form, a few solutions of matters that will frequently present themselves to the active worker:

Timber for Posts is rendered almost proof against rot by thorough seasoning, charring, and immersion in hot coal tar.

Increase in Strength of Different Woods by Seasoning.—White pine, 9 per cent.; elm, 12·3 per cent.; oak, 26·6 per cent.; ash, 44·7 per cent.; beech, 61·9 per cent.

Comparative Resilience of various Kinds of Timber.—Ash being 1, fir ·4, elm ·54, pitch pine ·57, teak ·59, oak ·63, spruce ·64, yellow pine ·64, cedar ·66, chestnut ·73, larch ·84, beech ·86. By resilience is meant the quality of springing back, or toughness.

To Bend Wood.—Wood enclosed in a close chamber, and submitted to the action of steam for a limited time, will be rendered so pliant that it may be bent in almost any direction. The same process will also eliminate the sap from the wood and promote rapid seasoning.

Fireproofing for Wood.—Alum, 3 parts; green vitriol, 1 part; make a strong hot solution with water; make another weak solution with green vitriol in which pipeclay has been mixed to the consistence of a paint. Apply two coats of the first dry, and then finish with one coat of the last.

To Prevent Wood from Cracking.—Place the wood in a bath of fused paraffin heated to 212° Fahr., and allow it to remain as long as bubbles of air are given off. Then allow the paraffin to cool down to its point of congelation, and remove the wood and wipe off the adhering wax. Wood treated in this way is not likely to crack.

Comparative Value of Different Woods, showing their crushing strength and stiffness:—Teak, 6,555; English oak, 4,074; ash, 3,571; elm, 3,468; beech, 3,079; American oak, 2,927; mahogany, 2,571; spruce, 2,522; walnut, 2,374; yellow pine, 2,193; sycamore, 1,833; cedar, 700.

Relative Hardness of Woods.—Taking shell-bark hickory as the highest standard, and calling that 100, other woods will compare with it for hardness as follows:—Shell-bark hickory, 100; pig-nut hickory, 96; white oak, 84; white ash, 77; dogwood, 75; scrub oak, 73; white hazel, 72; apple tree, 70; red oak, 69; white beech, 65; black walnut, 65; black birch, 62; yellow oak, 60; white elm, 58; hard maple, 56; red cedar, 56; wild cherry, 55; yellow pine, 54; chestnut, 52; yellow poplar, 51; butternut, 43; white birch, 43; white pine, 30.

Tensile Strength of Different Kinds of Woods, showing the weight or power required to tear asunder one square inch:—Locust, 25,000 lbs.; mahogany, 21,000 lbs.; box, 20,000 lbs.; bay, 14,500 lbs.; teak, 14,000 lbs.; cedar, 14,000 lbs.; ash, 14,000 lbs.; oak, seasoned, 13,600 lbs.; elm, 13,400 lbs.; sycamore, 13,000 lbs.; willow, 13,000 lbs; mahogany, Spanish, 12,000 lbs.; pitch pine, 12,000 lbs; white pine, 11,800 lbs.; white oak, 11,500 lbs.; lignum-vitæ, 11,800 lbs.; beech, 11,500 lbs.; chestnut, sweet, 10,500 lbs.; maple, 10,500 lbs.; white spruce, 10,290 lbs.; pear, 9,800 lbs.; larch, 9,500 lbs.; walnut, 7,800 lbs.; poplar, 7,000 lbs.; cypress, 6,000 lbs.

Cisterns.—The capacity of a cistern is estimated in gallons; 7½ gallons to a cubic foot, which, though not strictly correct, is near enough for practical purposes; hence, to get the contents of a cistern in gallons, multiply the product of the length, breadth, and depth of the inside, in feet, by 7½.

The following table will give the contents or capacities of cisterns from two to twenty-five feet in diameter, with a depth of ten inches. The number of gallons may be multiplied by the number of times ten inches will divide in the depth of the cistern; thus: I make a cistern forty-five inches deep and five feet in diameter, then I multiply 122·40 × 4·5 = 550·80 gallons, or nearly 551 gallons.

	Gallons.		Gallons.
2 feet	19·5	8 feet	313·33
2½ "	30·6	8½ "	353·72
3 "	44·06	9 "	396·56
3½ "	59·97	9½ "	461·40
4 "	78·33	10 "	489·20
4½ "	99·14	11 "	592·40
5 "	122·40	12 "	705·00
5½ "	148·10	13 "	827·4
6 "	176·25	14 "	959·6
6½ "	206·85	15 "	1101·6
7 "	239·88	20 "	1958·4
7½ "	275·40	25 "	3059·9

Stairs.—As this is a subject of considerable magnitude it is not intended to enter into it here any further than to state that the author of the present work has in preparation a thorough treatise on the subject, which will cover the whole ground of staircasings, bodies and handrailing, and it is intended that the work shall be

issued uniform with this work on carpentry, and sold at the same price; namely—one dollar.

There are a great many works on stairbuilding in the market, all of which possess more or less excellence, but none of which seem to reach the popular requirement, as they are written much above the heads of ordinary workmen, or they deal altogether with hand-railing, to the total exclusion of the carcass and body of the stair. In the forthcoming work an attempt will be made to remedy these defects by giving special attention to the carcass as well as the rail, and by putting everything connected with stairs in the plainest phraseology, and so that everyone may understand, whether he has a knowledge of geometry or not. The following table may be of use here, as it shows the relative proportions of treads and risers to each other, where it is possible to follow the figures here laid down. It sometimes happens, however, that both space and height will determine the width of tread and height of riser. When this occurs, the workman should adhere as closely as possible to the proportions herein given:

Width of Tread.	Height of Riser.
6 inches	8½ inches.
7 "	8 "
8 "	7½ "
9 "	7 "
10 "	6½ "
11 "	6 "
12 "	5½ "
13 "	5 "

The width of the tread does not include the "nosing" or projection. This will make a 12 inch tread about 13½ inches wide, as the step or tread will project 1½ inches, or at least, the thickness of the stuff. This projection never counts in the run as the projection of each tread stands over the tread below. The height of riser includes the thickness of the tread, so that the first riser requires to be narrower by the thickness of the tread than any of the risers placed above it. There is always one more riser than treads in every flight of stairs. This is owing to the fact that the floor at

the foot of the stairs, and the floor at the landing, take the places of treads, though not counted as such. The rules and hints given in the foregoing apply as well to winding as to straight stairs.

Winders are measured at their centres.

To estimate the cost of ordinary stairs, either open or cased, first calculate the number of feet per straight step, counting the step and riser and the strings adjacent, allowing generally 1 foot in length of string for each riser. Allow for timbering underneath such a part of the actual number of feet as may be required to represent its value when figured at the same price as other lumber. After ascertaining the number of feet in one straight step, as above, multiply by the whole number of risers in the stairs, allowing three for each winder or swelled step when the stairs are winding. An allowance of two will be enough when there is no furring underneath. Allow four for quarter platforms and six for half platforms. No allowance need be made usually for landings unless large. Double the cost of dressed lumber. Figure pine at 5 cents per foot. Figure oak at 6 cents per foot. Figure walnut at 10 cents per foot, costing 6 cents. For ornamental brackets of pine allow 15 cents each, or per foot or fascia. For oak or walnut allow 25 cents each, or per foot of facia. For plain railing put up, multiply number of square inches on cross section by 4 cents, which will be the price per foot. Figure crooks and ramps at three times their length; for small rails or toad-back rails add 12 per cent.

Figure ordinary turned ballusters, smoothed and dovetailed, 2-inch walnut, at 15 cents; 2¼-inch walnut, at 18 cents; 2½-inch walnut, at 22 cents; 2-inch oak, at 10 cents; 2¼-inch oak, at 15 cents; and 2½-inch oak, at 18 cents.

Figure plain turned newels, walnut, 42 cents per inch of diameter (bases dressed); oak at 35 cents per inch of diameter (bases dressed); octagon newels (bases dressed) walnut at 64 cents per inch of diameter, and oak at 55 cents per inch diameter; octagon panelled shaft, walnut, 85 cents per inch of diameter, and oak 75 cents per inch of diameter.

Special designs may be figured somewhat in the same manner, varying, however, as the design seems to require.

These prices, of course, are only approximately correct; but when reliable figures are absent, they will be found to answer the purpose with tolerable accuracy.

INCLINATIONS OF ROOFS.

The various kinds of coverings used on roofs are copper, lead, iron, tin, slates, tiles, shingles, gravel, felt, pitch and cement. If the inclination for slates is $26\frac{1}{2}°$, which is about the correct thing, the following table will show the proper degrees of inclination suitable for other materials.

Kind of Covering.	Inclination to the Horizon in Degrees.		Height of roof in parts of a Span.	Weight upon a square of roofing.*
	Deg.	Min.		
Tin	3	50	1-48	50 pounds.
Copper	3	50	1-48	100 "
Lead	3	50	1-48	700 "
Slates, large	22	00	1-5	1120 "
" ordinary	26	33	1-4	900 "
" fine	26	33	1-4	500 "
Plain Tiles	29	41	2-7	1780 "
Gravel				
Felt and Cement				

Roofs covered with felt, cement and gravel may have any inclination on which the gravel will stay during heavy rains. The best incline for a gravel roof in the latitude of New York is about $\frac{5}{8}$ of an inch to the foot; but for the South and Southwest, the inclination might be something less. Where bricks and cement are used for a roof covering, the surface might be "cambered" like a ship's deck, and then drained from both eaves; or the roof might have a slight inclination in one or more directions.

CONTENTS OF BOXES, BINS AND BARRELS.

For Winchester bushel, contents 2,150·42 cubic inches.

A box 9 inches $\times$ 9 inches $\times$ $6\frac{1}{2}$ inches deep will contain 1 peck.

A box 12 inches $\times$ 12 inches $\times$ $7\frac{1}{2}$ inches deep will contain $\frac{1}{2}$ bushel.

A box 14 inches $\times$ 14 inches $\times$ 11 inches deep will contain 1 bushel.

*Timber and boards included.

5-bushel box or bin: 30 inches × 30 inches × 12 inches deep, or 25 inches × 25 inches × 17 3-16 inches deep.

10-bushel bin: 30 inches × 30 inches × 24 inches deep, or 2 feet × 3½ feet × 21 5-16 inches deep, or 3½ feet × 3½ feet × 12 3-16 inches deep.

15-bushel bin: 3½ feet × 3½ feet × 18¼ inches deep, or 3 feet × 4 feet × 18⅝ inches deep.

20-bushel bin: 3½ feet × 3½ feet × 24⅜ inches deep, or 3½ feet × 4 feet × 21 5-16 inches deep, or 3 feet × 4 feet × 24⅞ inches deep.

25-bushel bin: 3 feet × 4 feet × 31⅛ inches deep, or 3½ feet × 4½ feet × 23 11-16 inches deep, or 3 feet × 5 feet × 24⅞ inches deep.

30-bushel bin: 3½ feet × 4½ feet × 28½ inches deep, or 3 feet × 5 feet × 29⅞ inches deep.

40-bushel bin: 4 feet × 5 feet × 29¾ inches deep, or 4 feet × 6 feet × 24⅞ inches deep.

50-bushel bin: 4 feet × 6 feet × 31⅛ inches deep, or 4½ feet × 7 feet × 23 11-16 inches deep, or 5 feet × 6 feet × 24⅞ inches deep.

A common flour barrel will hold about 3⅓ bushels of grain or other fine stuff.

For coarse stuff, such as turnips, potatoes, apples, etc., heaped measures are allowed for. Cubic contents of bushel 2,747·7 inches.

5-bushel box or bin: 30 inches × 30 inches × 15¼ inches deep, or 2 feet × 3 feet × 15¾ inches deep.

10-bushel bin: 2½ feet × 3½ feet × 21¾ inches deep, or 3 feet × 4 feet × 16 inches deep.

15-bushel bin: 3 feet × 4 feet × 23⅞ inches deep.

20-bushel bin: 3 feet × 4 feet × 32 inches deep, or 3½ feet × 4 feet × 27¼ inches deep.

25-bushel bin: 3½ feet × 4 feet × 34 inches deep, or 3 feet × 5 feet × 31¾ inches deep, or 3½ feet × 5 feet × 27¼ inches deep.

30-bushel bin: 3 feet × 5 feet × 38 inches deep, or 3½ feet × 5 feet × 32¾ inches deep.

40-bushel bin: 3½ feet × 6 feet × 36¼ inches deep, or 4 feet × 6 feet × 31¾ inches deep.

50-bushel bin: 4 feet × 6 feet × 39¾ inches deep, or 5 feet × 5 feet × 38⅛ inches deep, or 5 feet × 6 feet × 31¾ inches deep.

A common flour barrel will hold about 2½ bushels.

ARITHMETICAL SIGNS.

= Sign of equality, or equal to.
\+ " Addition, plus, or more.
— " Subtraction, minus, or less.
× " Multiplication.
÷ " Division.
: Is to. } Signs of Proportion.
:: So is. }
: To. }

√ Square root; when placed before a number, the square root is to be extracted, as, √64 = 8.

$\sqrt[3]{}$ Cube root; and signifies that the cube, or third root is to be extracted, as $\sqrt[3]{64} = 4$.

A number is said to be *squared* when it is multiplied by itself. To *cube* a number, is to multiply it three times by itself, as the cube of 4 is 4 × 4 × 4 = 64.

° Degrees, ′ minutes, ″ seconds.

In Duodecimals, ′ denotes *primes*, or twelfths; ″ *seconds*, or twelfths of primes; ‴ *thirds*, or twelfths of seconds; thus, the term 4 6′ 3″ reads, 4 ft. 6 in. and 3 twelfths.

· Decimal point, as, ·5 = five tenths, ·05 = five hundredths, 2·8 = 2 and eight tenths.

MENSURATION OF SUPERFICIES.

To Find the Area of a Square.

Rule.—Multiply the side by itself, or, in other words, the base by the perpendicular.

Example.—To find the area of a square whose side is 17 feet. 17 × 17 = 289, the area of the square in feet.

To find the side of a square, the area being given, extract the square root of the area.

To Find the Area of a Rectangle.

Rule.—Multiply the length by the breadth, and the product will be the area.

Example.—To find the area of the rectangle.

ft. in	
10·7	its length.
7·3	breadth.
74·1	
2·7·9	
Feet, 76·8·9	

To Find the Area of a Rhombus or Rhomboides.

Rule.—Multiply the base by the perpendicular height and half the product will be the area.

Multiply the length by the perpendicular breadth, and the product will be the area.

Let the side be 17 feet, and the perpendicular 15 feet, then

$17 \times 15 = 255$, the area required.

To Find the Area of a Triangle.

Rule.—Multiply the base by the perpendicular height, and half the product will be the area. Let the base of the triangle be 14 feet and the perpendicular height 9 feet, then

$14 \times 9 = 126 \div 2 = 63$ feet the area of the triangle.

Another Rule.—Add the three sides together, and from half the sum subtract each side separately; then multiply the half sum and the three sides together, and the square root of the product will be the area required.

Let the sides of a triangle be 30, 40, and 50 ft. respectively.

$$\frac{30+40+50}{2} = \frac{120}{} = 60, \text{ half the sum of the sides.}$$

$60 - 50 = 10$, first remainder.

$60 - 40 = 20$, second remainder.

$60 - 30 = 30$, third remainder.

Then $60 \times 10 \times 20, \times 30 = 360{,}000$.

And the square root of 360,000 is equal to 600, the area in ft.

Any Two Sides of a Right-Angled Triangle being given, to Find the Third Side.

1. When the base and perpendicular are given.

Rule.—To the square of the base add the square of the perpendicular, and the square root of the sum will give the hypothenuse.

Let the base of the right-angled triangle be 24, and the perpendicular 18, to find the hypothenuse or third side.

576 square of the base.

324 square of the perpendicular.

$576 + 324 = 900$.

And the square root of 900 is equal to 30 feet, the length of the third side.

2. When the hypothenuse and one side is given.

Rule.—Multiply the sum of the hypothenuse and one side by their difference; the square root of the product will give the other side.

If the hypothenuse of a right-angled triangle be 30, and the perpendicular 18, what will be the base?

$30 + 18 = 48$ sum of the two sides.

$30 - 18 = 12$ difference of the two sides.

$48 \times 12 = 576$.

To Find the Area of a Trapezium.

Rule.—Divide the trapezium into two triangles by a diagonal drawn from one angle of the figure to another. The areas of the triangles may be found by the rules already given, and the sums will give the area of the trapezium. It is unnecessary to give an example of this problem, as it would only be a repetition of what has been already given.

Irregular Polygons, or Many-sided Figures.

It is only necessary to reduce them into triangles and parallelo

grams, and, calculating these severally, to add them together; the sum will give the area of the figure.

In this manner the land-surveyor estimates the quantity of acres, roods and perches contained within certain boundaries, and it may be done with considerable accuracy by subdividing the space until the whole area is contained within a number of single figures. The carpenter and joiner, however, has seldom a necessity for this mode of proceeding, for it is customary, in all those cases where a surface has a variable height, to take the medium between the two extremes, and consider the superficies as a parallelogram. But, as the builder is sometimes required by circumstances to measure the ground which is chosen as the site of a building, it is necessary that he should be able to do so when required.

To Find the Diameter or Circumference of a Circle the Diameter or Circumference being Given.

1. To find the circumference, the diameter being given.

Rule.—As 7 is to 22, so is the diameter to the circumference.

Example.—If the diameter of a circle be 84·5 inches, what is the circumference.

As 7 is to 22·0, so is 84·5 to 265,751 the circumference required.

2. To find the diameter, the circumference being given.

Rule.—As 22 is to 7, so is the circumference to the diameter.

To Find the Area of a Circle.

1. When the diameter and circumference are both given.

Rule.—Multiply half the circumference by half the diameter, and the product will be the area.

2. When the diameter is given.

Rule.—Multiply the square of the diameter by ·7854, and the product will be the area, or the diameter by the circumference and divide by 4.

3. When the circumference is given.

Rule.—Multiply the square of the circumference by ·07958, and the product will be the area.

To Find the Area of a Sector of a Circle.

Rule.—Multiply the radius of the circle by one-half of the arc of the sector.

To Find the Area of the Segment of a Circle.

Rule.—Find the area of a circle having the same arc, and deduct the triangle formed between the two radii and the chord of the arc.

Properties of the Circle.

Diameter	× 3·14159	= circumference.
Diameter	× ·8862	= side of an equal square.
Diameter	× ·7071	= side of an inscribed square.
Radius squared	× ·314159	= area of circle.
Radius	× 6·28318	= circumference.
Circumference	÷ 3·14159	= diameter.

MEASUREMENTS OF SOLIDS.

To Find the Solidity of a Cube.

A cube is a solid enclosed by six equal square surfaces.

Rule.—Multiply the side of the square by itself and that product by the side of the square.

Example.—The side being 9 feet.

$9 \times 9 = 81$, then
$81 \times 9 = 729$ = the solidity required.

To Find the Solidity of a Parallelopipedon.

A parallelopipedon is a solid having six sides. Every opposite two being equal and parallel to each other.

Rule.—Multiply the length by the breadth, and the product by the depth, and it will give the solidity required.

Example.—Length 82 inches, breadth 54, depth 10 inches.

$82 \times 54 = 4428$, then
$4428 \times 10 = 44280$, the solidity required.

To Find the Solidity of a Prism.

A prism is a solid, the ends of which are parallel, equal, and of the same figure. Specific names are given to them, according to the form of their bases or ends.

Rule.—Multiply the area of the base by the perpendicular height, and the product will be the solidity required.

To find the solidity of a rectangular prism whose base is 30 inches, and height 53.

$30 \times 53 = 1590$, the solidity in inches.

To Find the Solidity of a Cylinder.

A cylinder is a round prism, having circles for its ends, and is formed by the revolution of a right line about the circumference of two equal circles parallel to each other.

Rule.—Multiply the area of the base by the perpendicular height of the cylinder, and it will give the solidity.

To Find the Solidity of a Sphere.

A sphere is a solid formed by the revolution of a semicircle round a fixed diameter.

Rule.—Multiply the cube of the diameter by ·5236, and the product will be the solidity.

For the Area of a Sphere.

Multiply the square of the diameter by 3·1416.

For the Circumference.

Multiply the diameter by 3·1416.

The surface of a *spherical segment* or zone may be found by multiplying the diameter by the height, and then by 3·1416.

The solidity of a *spherical segment* or zone may be found thus—to 3 times the square of the radius (or half of the diameter) add the square of the height, then multiply the sum by the height and the product by ·5236.

REGULAR POLYGONS.

Number of Sides.	Name.	Area when diam of inscribed circle = 1.	Area when side = 1.	Length of side when perpendicular = 1.	Perpendicular when side = 1.	Radius of circumscribed circle when side = 1.	Length of side when radius of circumscribed circle = 1.
3	Triangle	1·299	0·433	3·464	0·289	·577	1·732
4	Square	1·000	1·000	2·000	0·500	·707	1·414
5	Pentagon	·908	1·720	1·453	0·688	·851	1·176
6	Hexagon	·866	2·508	1·555	0·866	1·000	1·000
7	Heptagon	·843	3·634	·963	1·039	1·152	·868
8	Octagon	·828	4·828	·828	1·207	1·307	·765
9	Nonagon	·819	6·182	·728	1·374	1·462	·684
10	Decagon	·812	7·694	·650	1·539	1·618	·618
11	Undecagon	·807	9·366	·587			

Area of Polygons.

Rule.—Multiply the square of the side by the figures in column 2.

Trigon	3 sides	0·4330
Pentagon	5 sides	1·7203
Hexagon	6 sides	2·5981
Heptagon	7 sides	3·6339
Octagon	8 sides	4·8284
Nonagon	9 sides	6·1818
Decagon	10 sides	7·6942
Undecagon	11 sides	9·3656
Dodecagon	12 sides	11·1962

Surfaces and Solidities of Regular Bodies.

Rule.—For the "surface" multiply the square of the length of one of the edges by column 2, and for the solidity multiply the cube of the length by column 3.

		Surface.	Solidity.
Tetraedron	4 faces	1·7321	0·1178
Hexaedron	6 "	6·0000	1·0000
Octaedron	8 "	3·4641	0·4714
Dodecaedron	12 "	20·6458	7·6631
Icasaedron	20 "	8·6603	2·1817

Number for Calculating Areas.

Circum. of circle = Diam. × 3·1416, or by 3 1-7th.

Length of arc of circle = Take span from 8 times the chord of half the arc and one-third remainder = length of arc required.

Ditto when arc contains 120° = Span × 1·2092.

Area of circle = Square of diam. × ·7854.

Area of segment of circle = To twice square root of span *plus* square of rise *add* chord of half arc, the result *multiplied* by 4-15 of rise equals area.

Area when it contains 120° = Square of span × ·20473.

Area of sector of circle = Radius × half the length of arc.

Area of ellipse = Product of the two diameters × ·7834.

Area egg-shaped sewer = Square of transverse diameter × 1·1597.

Solidity of a cone = Area of base × one-third perpendicular height.

Solidity of globe = Cube of diameter × ·5236.

Prismoidal formula = Sum of end areas *plus* 4 times middle area multiplied by one-sixth of length.

Gunter's Chain.

Generally adopted in land surveying, is 22 yards in length, or 100 links of 7·92 inches long. The length was fixed at 22 yards because the square whose side is 22 contains exactly 1-10th of an acre—or 1 chain in width and 10 in length contains an acre; 80 chains make 1 mile, and a square mile is the square of 80, or 640 acres.

TABLE OF SPHERICAL CONTENTS.

Diameters.	Surfaces.	Capacities.
1	3·141	·523
2	12·567	4·188
3	28·274	14·137
4	50·265	33·51
5	78·540	65·45
10	314·159	523·6
15	706·9	1767·1
20	1256·6	4189·
25	1963·5	8181·
30	2827·	14137·
40	5026·	33510·

DRAWINGS AND DRAWING INSTRUMENTS.

Every carpenter should know how to measure drawings, and the more enterprising ones will not even rest satisfied with this, but will

NOTE.—The prismoidal formula applies to earthworks, casks, and truncated cones.

endeavor to obtain a knowledge of the use of drawing instruments and drafting generally. To aid him in this matter, I have thought it proper to embody the following hints and rules on the subject in the present work; but I would advise the ambitious workman to secure one of the standard works on "Drawing Instruments" of which there are many to be found in the book stores. Of course, where access can be had to an office where drafting is done, the student should visit there at once, as one hour's experience over a drawing-board is worth a week's study over a book. It does not take a very long while for a *good* workman to become a fair draftsman when once he settles down to work.

In constructing preparatory pencil-drawings, it is advisable, as a rule of general application, to make no more lines upon the paper than are necessary; and to make them as dark as is consistent with the distinctness of the work. And here I may remark the inconvenience of that arbitrary rule by which it is, by some, insisted that the pupils should lay down in pencil every line that is to be drawn, before finishing it in ink. It is often beneficial to ink in one part of a drawing, before touching other parts at all; it prevents confusion, makes the first part of easy reference, and allows of its being better done, as the surface of the paper inevitably contracts dust, and becomes otherwise soiled in the course of time, and therefore the sooner it is done with the better.

Circles and circular arcs should, in general, be inked in before straight lines, as the latter may be more readily drawn to join the former than the former the latter. When a number of circles are to be described from one centre, the smaller should be drawn and inked first, while the centre is in better condition. When a centre is required to bear some fatigue it should be protected with a thickness of stout card, glued or pasted over it, to receive the compass leg, or a piece of transparent horn should be used, or some other suitable material.

India-rubber is the ordinary medium for cleaning a drawing, and for correcting errors made in penciling. For slight work it is quite suitable; but its repeated application raises the surface of the paper, and imparts a greasiness to it, which spoils it for line drawing, espe-

cially if ink shading or coloring is to be applied. It is much better to leave trifling errors alone, if corrections by the pencil may be made alongside without confusion, as it is, in such a case, time enough to clear away superfluous lines when the inking is finished.

When ink lines to any considerable extent have to be erased, a small piece of damped soft sponge may be rubbed over them till they disappear. As, however, this process is apt to discolor the paper, the sponge must be passed through clean water, and applied again to take up the straggling ink. For small erasures of ink lines, a sharp erasing knife should be used; this is an instrument with a short triangular blade fastened to a wooden or ivory handle. A sharp rounded pen-blade applied lightly and rapidly does well, and the surface may be smoothed down by the thumb nail or a paper-knife handle. In ordinary working drawings a line may readily be taken out by damping it with a hair pencil and quickly applying the india-rubber; and, to smooth the surface so roughened, a light application of the knife is expedient. In drawings intended to be highly finished, particular pains should be taken to avoid the necessity for corrections, as everything of this kind detracts from the appearance.

In using the square the more convenient way is to draw lines off the left edge with the right hand, holding the stock steadily, but not tightly, against the edge of the board with the left hand. The convenience of the left edge for drawing by is obvious, as we are able to use the arms more freely, and we see exactly what we are doing.

To draw lines in ink with the least amount of trouble to himself, the draftsman ought to take the greater amount of trouble with his tools. If they be well made, and of good stuff originally, they ought to last through three generations of draftsmen; their working parts should be carefully preserved from injury; they should be kept well set, and above all, scrupulously clean. The setting of instruments is a matter of some nicety, for which purpose a small oil-stone is convenient. To dress up the tips of the blades of the pen, or of the bows, as they are usually worn unequally by the customory usage, they may be screwed up into contact in the first

place, and passed along the stone, turning upon the point in a directly perpendicular plane, till they acquire an identical profile. Being next unscrewed, and examined to ascertain the parts of unequal thickness round the nib, the blades are laid separately upon their back on the stone and rubbed down at the points till they are brought up to an edge of uniform fineness. It is well to screw them together again, and to pass them over the stone once or twice more, to bring up any fault; to retouch them also on the outer and inner side of each blade, to remove barbs or frazing; and finally to draw them across the palm of the hand.

The India-ink, which is commonly used for line-drawing, ought to be rubbed down in water to a certain degree—avoiding the sloppy aspect of light lining in drawings, and making the ink just so thick as to run freely from the pen. This medium degree may be judged of after a little practice by the appearance of the ink on the pallet. The best quality of ink has a soft feel, free from grit or sediment when wetted and rubbed against the teeth, and it has a musky smell. The rubbing of India-ink in water tends to crack and break away the surface at the point; this may be prevented by shifting at intervals the position of the stick in the hand while being rubbed, and thus rounding the surface. Nor is it advisable, for the same reason, to bear very hard, as the mixture is otherwise more evenly made, and the enamel of the pallet is less rapidly worn off. When the ink, on being rubbed down, is likely to be for some time required, a considerable quantity of it should be prepared, as the water continually vaporizes; it will thus continue for a longer time in a condition fit for application. The pen should be levelled in the ink, to take up a sufficient charge; and to induce the ink to enter the pen freely, the blades should be lightly breathed upon or wetted before immersion. After each application of ink the outsides of the blades should be cleaned, to prevent any deposit of ink upon the edge of the square.

To keep the blades of his *inkers* clean is the first duty of a draftsman who is to make a good piece of work. Pieces of blotting or unsized paper, and cotton velvet, washleather, or even the sleeve of a coat, should always be at hand while a drawing is being

inked. When a small piece of blotting paper is folded twice, so as to present a corner, it may usefully be passed between the blades of the pen, now and then, as the ink is liable to deposit at the point and obstruct the passage, particularly in fine-lining; and for this purpose the pen must be unscrewed to admit the paper. But this process may be delayed by drawing the point of the pen over a piece of velvet, or even over the surface of thick blotting paper; either method clears the point for a time. As soon as any obstruction takes place the pen should be immediately cleaned, as the trouble thus taken will always improve and expedite the work. If the pen should be laid down for a short time with the ink in it, it should be unscrewed to keep the points apart, and so prevent deposit; and when done with altogether for the occasion, it ought to be thoroughly cleaned at the nibs. This will prevent rusting, and preserve its edges.

In coloring drawings it is necessary to have good brushes, or camel's-hair pencils for the purpose; these can be purchased from any dealer who keeps painter's materials. The point of each brush should be as fine as the point of a small needle, and when the brush is bent over after being wetted, the hairs should remain in a compact bunch without any separation whatever. If it should split up into several parts during the operation of bending to and fro, it should be examined, and all short hairs found in the centre removed. Bright clear lines are made by having the ink *very dark.*

Never intersect lines until the first lines drawn are dry.

Tapering lines are made by successive closings of the pen, or by a dexterity in adjusting its position to the paper and the pressure upon it.

When it is intended to tint drawings with ink or colors, the following rules should be observed: (1) The paper should have the superfluous sizing removed by being sponged lightly with clean water. (2) The paper, and everything about it, must be kept perfectly clean. (3) Line off the spaces with *very fine* pencil marks, that are to be tinted. (4) Never use the eraser on the part to be tinted, either before or after the tinting. (5) Try the tinting process on a piece of waste paper until the proper tint is obtained, before applying to the drawing. (6) Dark tints are formed by applying

a number of light ones over each other, but a second tint should not be applied until the first one is perfectly dry. (7) Always finish tinting one portion of drawing before leaving it. Otherwise it will be cloudy. (8) See that the paper is damp before you begin to tint. (9) Ink in all lines after the tinting is completed and the drawing is perfectly dry.

The following arrangement shows how the various materials are represented in a drawing, but in my experience I have always found it the better way to leave all working drawings in ink alone. An ink drawing nicely finished, has a far more artistic appearance than one that is colored, unless the latter is made by a master hand.

Materials.	*Color.*
Brickwork in plans and sections	Crimson lake.
Brickwork in elevations	Crimson lake mixed with burnt sienna or Venetian red.
The lighter woods, such as pine	Raw sienna.
Oak or ash	Vandyke brown.
Granite	Pale Indian ink.
Stone generally	Yellow ochre, or pale sepia.
Concrete works	Sepia with darker markings.
Wrought iron	Indigo.
Cast iron	Payne's grey or neutral tint.
Steel	Pale indigo tinged with lake.
Brass	Gamboge or Roman ochre.
Lead	Pale Indian ink tinged with indigo.
Clay or earth	Burnt umber.
Slate	Indigo and lake.

DRAWING PAPER.

Drawing paper, properly so called, is made to certain standard sizes, as follows:

Demy	20 × 15 inches.
Medium	22 × 17 "
Royal	24 × 17 "

Super-Royal	27 × 19	inches.
Imperial	30 × 22	"
Elephant	28 × 23	"
Columbia	34 × 23	"
Atlas	34 × 26	"
Double Elephant	40 × 27	"
Antiquarian	53 × 31	"
Emperor	68 × 48	"

Of these, Double Elephant is the most generally useful size of sheet. Demy and Imperial are the other useful sizes. Whatman's white paper is the quality usually employed for finished drawings; it will bear wetting and stretching without injury, and, when so treated, receives shading and coloring easily and freely. Common papers will answer for drawings where no damping or stretching is required. Large drawings, that are frequently referred to, should be mounted on linen, previously damped, with a free application of paste.

Drawing paper also comes in rolls of indefinite lengths, and from 36 to 54 inches wide. It is made different tints, is generally very tough, and is chiefly used for details; it is much cheaper than Whatman's, and for many purposes answers just as well. Tracing cloth, also, comes in rolls, 18, 30, 36, and 42 inches wide; it is convenient and durable, and may be folded up almost any number of times without injury.

Tracing paper is made of different qualities and sizes; it is rendered transparent, and qualified to receive ink lines and tinting without spreading. Like tracing cloth, when placed over a drawing already executed, the drawing is distinctly visible through the paper, and may be copied or traced directly by the ink instruments; thus an accurate copy may be made with great expedition.

BOARD MEASURE.

Explanation of Table.—The left-hand column shows the width of each board in inches. At the heads of the remaining columns will be found the lengths of the boards in feet. The contents of each board is given in square feet and *primes* or 12th parts of a

square foot, 1 prime being equal to 12 square inches. For example, a board 8 inches wide and 4 feet long contains 2 square feet and 8 *primes*, or 96 square inches.

Operation.

Bringing 4 feet to inches thus: $4 \times 12 = 48$ inches. Then $48 \times 8 = 384$. Lastly: $144)384(2$
288
96

Thus a board 4 feet long and 8 inches wide contains 2 square feet, and 8-12 of a square foot or 96 square inches. In constructing the following table the remaining square inches (after dividing by 144 to bring the inches to feet) are divided by 12, and the quotient is termed *primes*.

Boards are sold by superficial measurement, at so much per foot of an inch or *less* in thickness; adding one-fourth to the price for each quarter of an inch thickness over an inch. It sometimes happens that a board is *tapering*, being wider at one end than the other. When this is the case (if it be a true taper), add the width of both ends together, and half their sum will express the average width of the board. Again: if the board does not taper regularly, take the following course to find its area: I. Measure the breadths at several places equi-distant. II. Add together the different breadths, and half the two extremes. III. Multiply this sum by the straight side of the board and divide the product by the number of parts into which the board was divided. It is usual in measuring rough lumber, to pay no attention to fractions of an inch in the width of the stuff. If the fraction is more than half an inch it is counted as an inch; if less than half an inch it is not counted. Thus, a board 10⅝ inches wide, would be measured as 11 inches wide; if only 10⅜ inches wide the board will pass only as 10 inches wide. When the fraction is just a half an inch, it is sometimes counted and sometimes not. Local usage, however, sometimes runs contrary to this practice, and the fractions are not taken into consideration at all. The widths are all measured by whole numbers.

LENGTH IN FEET.

Inches in Width.	3 feet.	4 feet.	5 feet.	6 feet.	7 feet.	8 feet.	9 feet.
1	0·3	0·4	0·5	0·6	0·7	0·8	0·9
2	0·6	0·8	0·10	1·0	1·2	1·4	1·6
3	0·9	1·0	1·3	1·6	1·9	2·0	2·3
4	1·0	1 4	1·8	2·0	2·4	2·8	3·0
5	1·3	1·8	2·1	2·6	2·11	3.4	3·9
6	1.6	2·0	2·6	3·0	3·6	4 0	4·6
7	1·9	2·4	2·11	3·6	4·1	4·8	5·3
8	2·0	2·8	3·4	4·0	4·8	5·4	6·0
9	·3	3·0	3·9	4·6	5·3	6·0	6·9
10	½·6	3·4	4·2	5·0	5·10	6·8	7·6
11	2·9	3·8	4 7	5·6	6·5	7·4	8·3
12	3·0	4·0	5·0	6·0	7·0	8·0	9·0
13	3·3	4·4	5·5	6·6	7·7	8·8	9·9
14	3·6	4·8	5·10	7·0	8·2	9·4	10·6
15	3·9	5·0	6·3	7·6	8·9	10·0	11·3
16	4·0	5·4	6·8	8·0	9·4	10·8	12·0
17	4·3	5·8	7·1	8·6	9·11	11·4	12·9
18	4·6	6·0	7·6	9·0	10·6	12·0	13·6
19	4·9	6·4	7·11	9·6	11·1	12·8	14·3
20	5·0	6·8	8·4	10·0	11·8	13·4	15·0
21	5·3	7·0	8 9	10·6	12·3	14·0	15.9
22	5 6	7·4	9·2	11·0	12·10	14·8	16·6
23	5·9	7·8	9·7	11·6	13·5	15·4	17·3
24	6·0	8·0	10·0	12·0	14·0	16·0	18·0
25	6·3	8·4	10·5	12·6	14·7	16·8	18·9
26	6·6	8·8	10·10	13·0	15·2	17·4	19·6
27	6·9	9·0	11·3	13·6	15·9	18·0	20·3
28	7·0	9·4	11·8	14·0	16·4	18·8	21·0
29	7·3	9·8	12·1	14·6	16·11	19·4	21·9
30	7·6	10 0	12·6	15·0	17·6	20·0	22·6
31	7·9	10·4	12·11	15·6	18·1	20 8	23·3
32	8·0	10 8	13·4	16·0	18·8	21·4	24·0
33	8·3	11·0	13·9	16·6	19·3	22·0	24·9
34	8·6	11·4	14·2	17·0	19·10	22·8	25·6
35	8·9	11·8	14·7	17·6	20·5	23·4	26·3
36	9·0	12·0	15·0	18·0	21·0	24·0	27·0

LENGTH IN FEET.

Inches in Width.	10 feet.	11 feet.	12 feet.	13 feet.	14 feet.	15 feet.	16 feet.	17 feet.	18 feet.
1	0·10	0·11	1·0	1·1	1·2	1·3	1·4	1·5	1·6
2	1·8	1·10	2·0	2·2	2·4	2·6	2·8	2·10	3·0
3	2·6	2·9	3·0	3·3	3·6	3·9	4·0	4·3	4·6
4	3·4	3·8	4·0	4·4	4·8	5·0	5·4	5·8	6·0
5	4·2	4·7	5·0	5·5	5·10	6·3	6·8	7·1	7·6
6	5·0	5·6	6·0	6·6	7·0	7·6	8·0	8·6	9·0
7	5·10	6·5	7·0	7·7	8·2	8·9	9·4	9·11	10·6
8	6·8	7·4	8·0	8·8	9·4	10·0	10·8	11·4	12·0
9	7·6	8·3	9·0	9·9	10·6	11·3	12·0	12·9	13·6
10	8·4	9·2	10·0	10·10	11·8	12·6	13·4	14·2	15·0
11	9·2	10·1	11·0	11·11	12·10	13·9	14·8	15·7	16·6
12	10·0	11·0	12·0	13·0	14·0	15·0	16·0	17·0	18·0
13	10·10	11·11	13·0	14·1	15·2	16·3	17·4	18·5	19·6
14	11·8	12·10	14·0	15·2	16·4	17·6	18·8	19·10	21·0
15	12·6	13·9	15·0	16·3	17·6	18·9	20·0	21·3	22·6
16	13·4	14·8	16·0	17·4	18·8	20·0	21·4	22·8	24·0
17	14·2	15·7	17·0	18·5	19·10	21·3	22·8	24·1	25·6
18	15·0	16·6	18·0	19·6	21·0	22·6	24·0	25·6	27·0
19	15·10	17·5	19·0	20·7	22·2	23·9	25·4	26·11	28·6
20	16·8	18·4	20·0	21·8	23·4	25·0	26·8	28·4	30·0
21	17·6	19·3	21·0	22·9	24·6	26·3	28·0	29·9	31·6
22	18·4	20·2	22·0	23·10	25·8	27·6	29·4	31·2	33·0
23	19·2	21·1	23·0	24·11	26·10	28·9	30·8	32·7	34·6
24	20·0	22·0	24·0	26·0	28·0	30·0	32·0	34·0	36·0
25	20·10	22·11	25·0	27·1	29·2	31·3	33·4	35·5	37·6
26	21·8	23·10	26·0	28·2	30·4	32·6	34·8	36·10	39·0
27	22·6	24·9	27·0	29·3	31·6	33·9	36·0	38·3	40·6
28	23·4	25·8	28·0	30·4	32·8	35·0	37·4	39·8	42·0
29	24·2	26·7	29·0	31·5	33·10	36·3	38·8	41·1	43·6
30	25·0	27·6	30·0	32·6	35·0	37·6	40·0	42·6	45·0
31	25·10	28·5	31·0	33·7	36·2	38·9	41·4	43·11	46·6
32	26·8	29·4	32·0	34·8	37·4	40·0	42·8	45·4	48·0
33	27·6	30·3	33·0	35·9	38·6	41·3	44·0	46·9	49·6
34	28·4	31·2	34·0	36·10	39·8	42·6	45·4	48·2	51·0
35	29·2	32·1	35·0	37·11	40·10	43·9	46·8	49·7	52·6
36	30·0	33·0	36·0	39·0	42·0	45·0	48·0	51·0	54·0

AMERICAN WEIGHTS AND MEASURES.

Lineal Measure.

12 inches	1 foot.
3 feet	1 yard.
16 ft. 6 ins. or 5½ y'ds.	1 rod.
220 yards or 40 rods	1 furlong
1760 yards or 8 furlongs.	1 mile.
7·22 inches	1 link.
100 links or 66 feet	1 chain.
10 chains	1 furlong.
80 chains	1 mile.
69½ statute miles or 60 geographical miles	1 degree of the equator
8 furlongs	1 mile.
3 miles	1 league.

Square Measure.

144 square inches	1 foot.
9 square feet	1 yard.
100 " "	1 square.
272¼ " " or 30¼ square yards 40 square rods	1 rod, pole or perch.
4 square rods or 4840 yards	1 acre.
10,000 square links	1 sq. chain
10 sq. chains 100,000 sq. links	1 sq. acre.
640 acres	1 sq. mile.

Cubic Measure.

1728 cubic inches	1 cubic ft.
27 cubic feet	1 cubic yd.
40 feet of round or 50 ft. of hewn timb.	1 ton.
45 cubic feet	1 ton of shipping.
8 cord feet or 128 cubic feet	1 cord.

Circular Measure.

60 seconds	1 minute.
60 minutes	1 degree.
15 degrees	1 hour angle
30 degrees	1 sign.
12 signs or 360 degrees.	1 circle.

Books.

A sheet folded in 2 leaves			a folio.
"	4	"	a quarto or 4to.
"	8	"	an octavo or 8vo.
"	12	"	a 12 mo.
"	16	"	a 16 mo.
"	18	"	a 18 mo.
"	24	"	a 24 mo.
"	32	"	a 32 mo.

DECIMAL APPROXIMATIONS FOR FACILITATING CALCULATIONS.

Lineal feet multiplied by	·00019	= miles.
" yards "	·000598	= "
Square inches "	·007	= square feet.
" feet "	·111	= square yards.
" yards "	·0002067	= acres.
Circular inches "	·00546	= square feet.
" feet "	·02909	= cubic yards.
Cubic inches "	·00058	= cubic feet.
" feet "	·03704	= cubic yards.
" " "	6·2321	= imperial gallons
" inches "	·003607	= " "
Bushels "	·0476	= cubic yards.
" "	1·284	= cubic feet.

AUTHORIZED METRIC SYSTEM.

Measures of Length.

Metric Denominations and Values.		Equivalents in Denominations in Use.
Myriametre	10,000 metres.	6·2137 miles.
Kilometre.....	1,000 metres.	0·62137 miles, or 3,280 feet 10 inches.
Hectometre.....	100 metres	328 feet and 1 inch.
Decametre	10 metres	393·7 inches.
METRE	1 metre	39·37 inches.
Decimetre	1-10 of a metre.....	3·937 inches.
Centimetre.....	1-100 of a metre.....	0·3937 inch.
Millimetre.....	1-1000 of a metre.....	0·0394 inch.

Measures of Surfaces.

Metric Denominations and Values		Equivalents in Denominations in Use.
Hectare	10,000 square metres.....	2·471 acres.
Are	100 square metres.....	119·6 square yards.
CENTARE.	1 square metre	1550 square inches.

Measures of Capacity.

Metric Denominations and Values.			Equivalents in Denominations in Use.	
Names.	No. of Litres	Cubic Measure.	Dry Measure.	Liquid or Wine Measure.
Kilolitre, or stere..	1,000	1 cubic metre	1·308 cubic yard..	264·17 gallons.
Hectolitre	100	1-10 of a cubic metre.....	2 bush. 3·35 pk...	26·417 gallons.
Decalitre	10	10 cubic decimetres.....	9·08 quarts	2·6417 gallons.
LITRE.....	1	1 cubic decimetre.....	0·908 quart	1·0567 quarts.
Decilitre.....	1-10	1-10 of a cubic decimetre.	6·1022 cub. in...	0·845 gill.
Centilitre.....	1-100	10 cubic centimetres.....	0·6102 cub. in....	0·338 fluid oz.
Millilitre.....	1-1000	1 cubic centimetre	0·061 cub. in.....	0·27 fluid dr.

Weights.

Metric Denominations and Values.			Equivalents in Denominations in Use.
Names.	No of grammes.	Weight of what quantity of water at maximum density.	Avoirdupois Weight.
Millier, or tonneau	1,000,000	1 cubic metre	2204·6 pounds
Quintal	100,000	1 hectolitre	220·46 pounds
Myriagramme	10,000	10 litres	22·046 pounds
Kilogramme, or kilo	1,000	1 litre	2·2046 pounds
Hectogramme	100	1 decilitre	3·5274 ounces
Decagramme	10	10 cubic centimetres	0·3527 ounce
GRAMME	1	1 cubic centimetres	15·432 grains
Decigramme	1-10	1-10 of a cubic centimetre	1·5432 grain
Centigramme	1-100	10 cubic millimetres	0·1543 grain
Milligramme	1-1000	1 cubic millimetre	0·0154 grain

GEOGRAPHICAL OR NAUTICAL MEASURE.

6 feet = 1 fathom.
110 fathoms, or 660 feet = 1 furlong.
6075 4-5 feet = 1 nautical mile.
3 nautical miles = 1 league.
20 leagues, or 60 geographical miles = 1 degree.
360 degrees = the circumference of the earth, or 24,855½ miles, nearly.

The nautical mile exceeds the common one by 795 4-5 feet.

MEASURE OF TIME.

60 seconds = 1 minute.
60 minutes = 1 hour.
24 hours = 1 day.
7 days = 1 week.
28 days = 1 lunar month.
28, 29, 30, or 31 days = 1 cal. month.
12 calendar months = 1 year.
365 days = 1 com. year.
366 days = 1 leap year.
365¼ days = 1 Julian year.

365 days, 5 hours, 48 minutes, 49 seconds = 1 solar year.
365 days, 6 hours, 9 minutes, 12 seconds = 1 siderial year.

ON CONTRACTS AND SPECIFICATIONS.

It frequently happens, in villages and country towns, that the carpenter will not only be called upon to make drawings or pencil sketches of cottages, barns, stables, fences, etc., etc., but he will be expected to make specifications for same with bills of lumber and all the necessary details connected therewith. A form for a specification would take up too much space here to be given, and it is quite unnecessary, for printed forms can be purchased for 35 cents each, which can be filled in in a very short time. It is much better for the country workman to use these forms in every case, as they

will prove reminders of many things that might otherwise be forgotten.

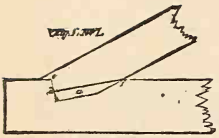
Though a form of specification may not be necessary for the reason given, yet it is thought that a short pithy form of contract might prove useful, as frequently there is no other agreement in writing between workmen and owners than a short written contract. The following may be changed to suit conditions:

FORM OF CONTRACT FOR BUILDING.

Made the ——— day of ————————, one thousand eight hundred and ———, by and between ————————————, of the second part, in these words; the said ——— part ——— of the second part *covenant*, and *agree* to and with the said party of the first part, to make, erect, build, and finish, in a good substantial, and workmanlike manner, on the ———————————————————— agreeable to the draft, plan, and explanation hereto annexed, of good and substantial material, by the ———————— day of ———————— next. And the party of the first part covenants and agrees to pay unto the said ——— part ——— of the second part, for the same, the sum of ———————————————————, lawful money of the United States, as follows: The sum of ————————————, and for the true and faithful performance of all and every of the covenants and agreements above mentioned, the parties to these presents bind themselves each unto the other, in the penal sum of ———————————— dollars; as affixed and settled damages to be paid by the failing party.

IN WITNESS WHEREOF, the parties to these presents have hereunto set their hands and seals, the day and year above written.

Sealed and delivered in the presence of ————————————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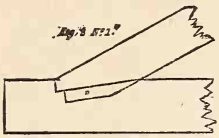
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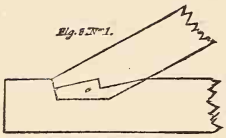
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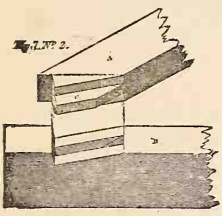
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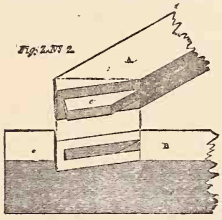
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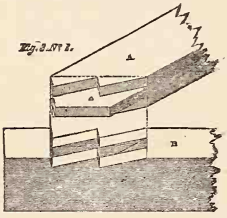
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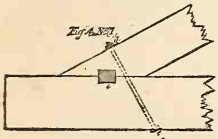
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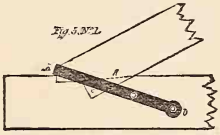
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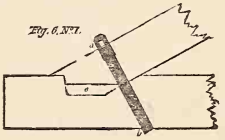
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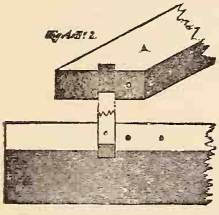
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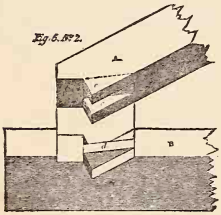
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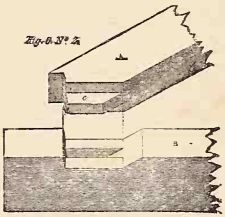
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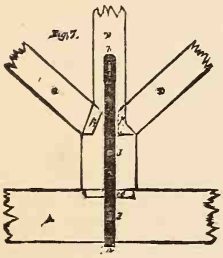
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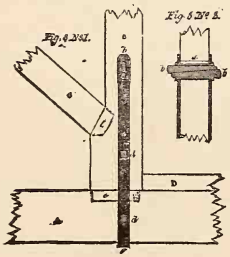
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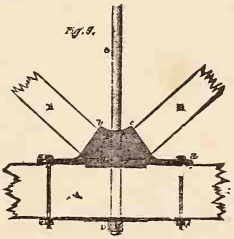
Fig. 8. N° 2.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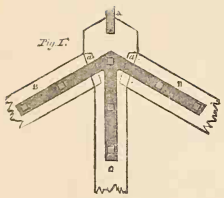
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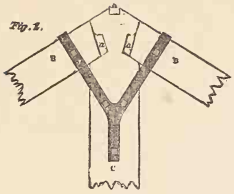
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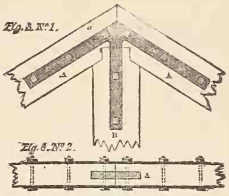
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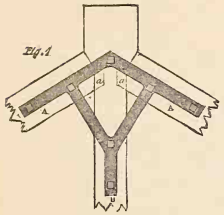
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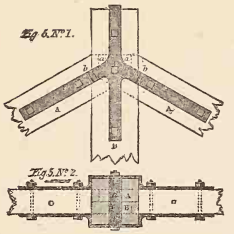
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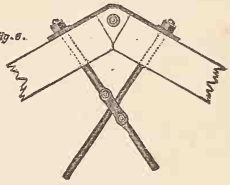
Fig. 5. N° 2.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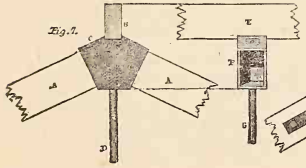
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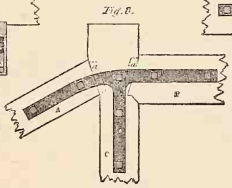
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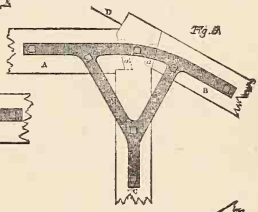
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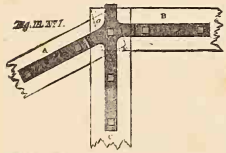
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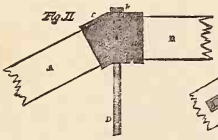
Fig. 10. N° 2.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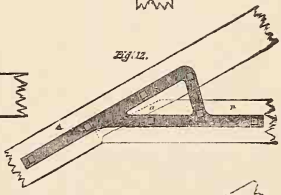
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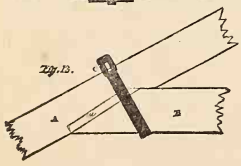
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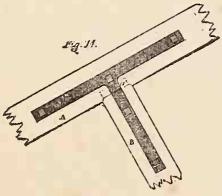
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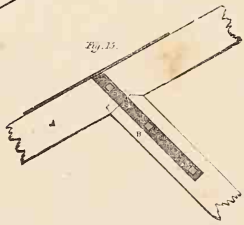
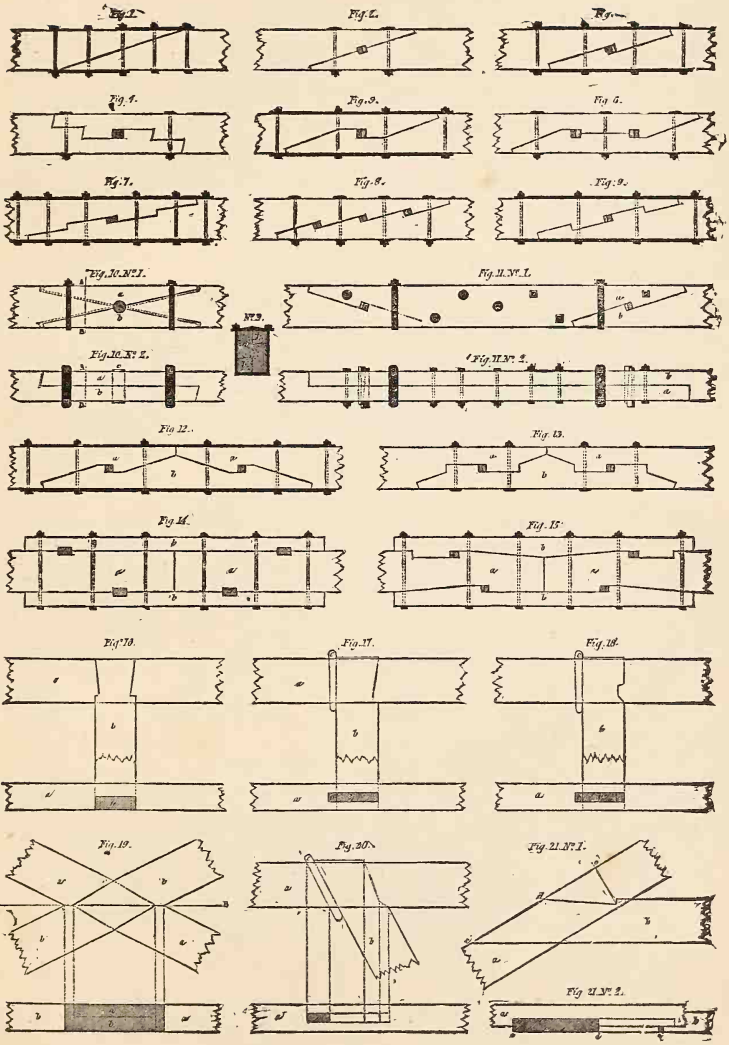


Fig. 15.

PLATE III.

JOINTS.

SCARFING, LENGTHENING-BEAMS &c.



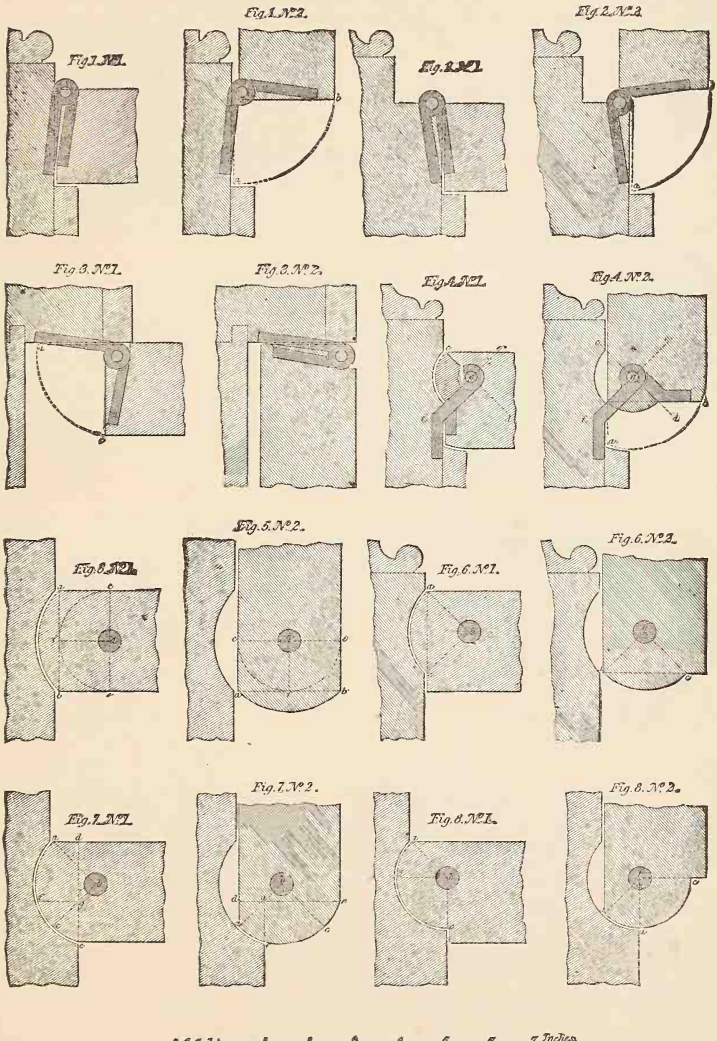


Fig.1.N°1.
Fig.1.N°2.
Fig.2.N°1.
Fig.2.N°2.
Fig.3.N°1.
Fig.3.N°2.
Fig.4.N°1.
Fig.4.N°2.
Fig.5.N°1.
Fig.5.N°2.
Fig.6.N°1.
Fig.6.N°2.
Fig.7.N°1.
Fig.7.N°2.
Fig.8.N°1.
Fig.8.N°2.
Inches

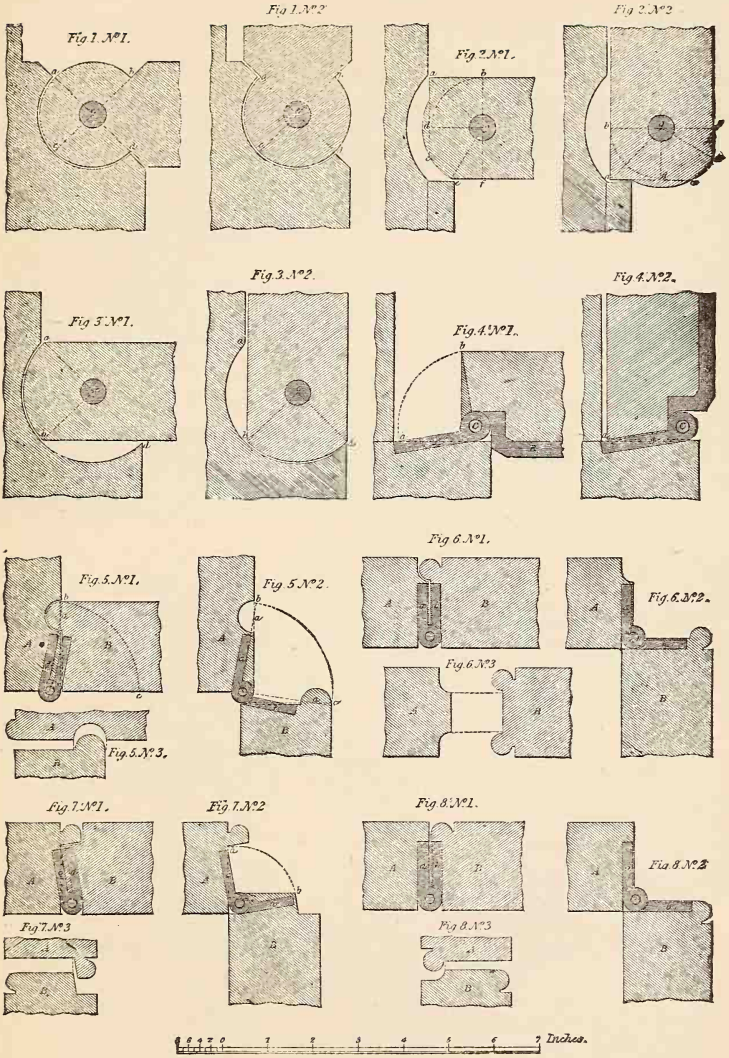
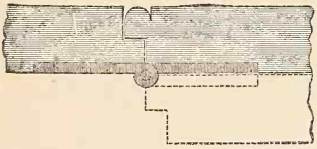


Fig 1. N°1.
Fig 1. N°2
Fig 2. N°1.
Fig 2. N°2
Fig 3. N°2.
Fig 3. N°1.
Fig 4. N°2.
Fig 4. N°1.
Fig 5. N°1.
Fig 5. N°2.
Fig 5. N°3.
Fig 6. N°1.
Fig 6. N°2.
Fig 6. N°3
Fig 7. N°1.
Fig 7. N°2
Fig 7. N°3
Fig 8. N°1.
Fig 8. N°2
Fig 8. N°3
Inches.

Fig. 1.



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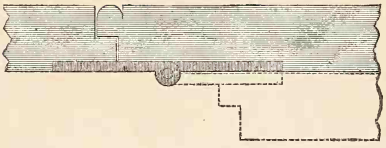
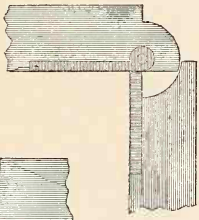


Fig. 3. N°1.

Fig. 3. N°2.



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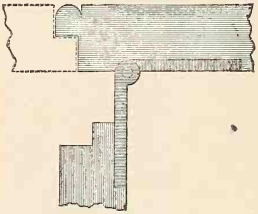


Fig. 4. N°1.

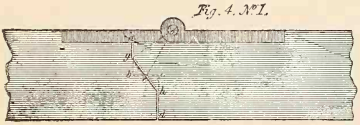
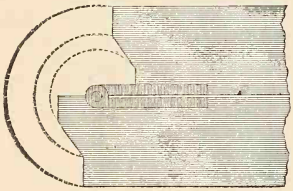


Fig. 4. N°2.



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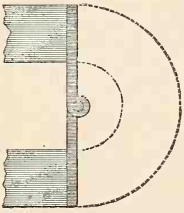
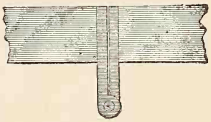


Fig. 5. N°1.



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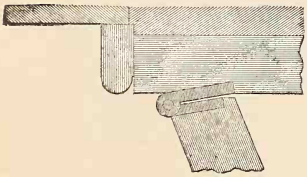
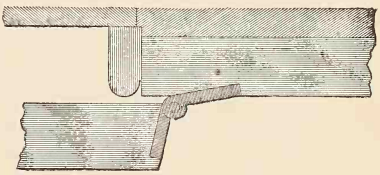


Fig. 6. N°2.



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